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MEASURING AND APPRAISING CAPACITY IN FISHERIES: FRAMEWORK, ANALYTICAL TOOLS AND DATA AGGREGATION

by
S. Pascoe
Centre for the Economics and Management of Aquatic Resources
University of Portsmouth
Portsmouth, United Kingdom

D. Gréboval
Fishery Policy and Planning Division
FAO Fisheries Department
Rome, Italy

J. Kirkley
College of William and Mary
Virginia Institute of Marine Science
Gloucester Point, Virginia
United States of America

E. Lindebo
Danish Research Institute of Food Economics
Frederisksberg C.,Denmark

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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PREPARATION OF THIS CIRCULAR

In 1998, FAO organized a Technical Working Group (TWG) to discuss issues related to fishing capacity. Major issues discussed included measurement and control methods for managing and reducing capacity. The FAO meeting also served as a basis for the development of an International Plan of Action (IPOA) for the Management of Fishing Capacity. The FAO Committee on Fisheries adopted the IPOA in February 1999. A subsequent FAO Technical Consultation was held in Mexico City in 1999. The purpose of that meeting was to better define capacity and capacity utilization in fisheries, and to examine methods or develop general guidelines that might be used to estimate capacity and excess capacity in fisheries.

Since the 1988 meeting, considerable activity has been undertaken by FAO in studying fishing capacity. This has culminated in several reports, including:

- Report of the Technical Working Group (TWG) meeting on the Management of Fishing Capacity (FAO Fisheries Report No. 586, 1998).
- Selected papers from the TWG Meeting (FAO Fisheries Technical Paper No. 386, 1999).
- International Plan of Action on the Measurement of Fishing Capacity (1999).
- Report of the Technical Consultation on the Measurement of Fishing Capacity (FAO Fisheries Report No. 615, 2000).
- A review of policy and technical issues involved in managing capacity (FAO Fisheries Technical Paper No. 409, 2001).
- Report on the Expert Consultation on Catalysing the Transition away from Overcapacity in Marine Capture Fisheries (FAO Fisheries Report No. 691, 2002).
- Selected papers from the Technical Consultation on the Measurement of Fishing Capacity (FAO Fisheries Technical Paper No. 445, 2003).

A recent report also reviews methods for assessing and managing fishing capacity. The report is in two volumes, published separately. Part 1 provides an overview of basic concepts for the assessment and management of fishing capacity; and Part 2 provides more details on methods for measuring and assessing capacity (FAO Fisheries Technical Papers No. 433/1 and 433/2, 2004).

The present document complements the above documentation and the last document (Technical Paper No. 433) in particular. It includes two papers on the measurement of fishing capacity.

The first paper is introductory and provides a general framework for measurement and assessment. Capacity analysis can indeed assist fisheries managers in obtaining more information on the underlying capacity issues of fishing fleets, in terms of efficiency, productivity and overall balance with available resources.

The second paper presents a practical and illustrative application of these analyses in an empirical setting for the fishing industry. Many tools are available that can be readily applied to input/output data of fishing fleets. Five such approaches are considered in the context of economic theory, namely catch-per-unit-effort, variable input utilization, peak-to-peak, data envelopment analysis and break-even analysis.

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Measuring and appraising capacity in fisheries: framework, analytical tools and data aggregation
FAO Fisheries Circular. No. 994. Rome, FAO. 2004. 39p.

ABSTRACT

The present document includes two papers on the measurement of fishing capacity and completes existing FAO documentation on this topic.

The first paper is introductory and provides a general framework for measurement and assessment. Capacity analysis can indeed assist fisheries managers in obtaining more information on the underlying capacity issues of fishing fleets, in terms of efficiency, productivity and overall balance with available resources.

The second paper presents a practical and illustrative application of these analyses in an empirical setting for the fishing industry. Many tools are available that can be readily applied to input/output data of fishing fleets. Five such approaches are considered in the context of economic theory, namely catch-per-unit-effort, variable input utilization, peak-to-peak, data envelopment analysis and break-even analysis.

Authors addresses:

Sean Pascoe
Centre for the Economics and Management of Aquatic Resources (CEMARE),
University of Portsmouth
Boathouse No. 6, College Road, HM Naval Base
Portsmouth PO 1 3LJ, United Kingdom
Email: sean.pascoe@port.ac.uk
Fax: +44 23 92844037

Dominique Gréboval
Fishery Policy and Planning Division
Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla, 00100 Rome, Italy
Email: Dominique.Greboval@fao.org

Jim Kirkley
College of William and Mary, Virginia Institute of Marine Science,
School of Marine Science, Gloucester Point, VA 23062, United States of America
Email: jkirkley@vims.edu
Fax: +1 804 684 7843

E. Lindebo
Danish Research Institute of Food Economics (FOI)
Rolighedsvej 25, 1958 Frederiksberg C. Denmark
E-mail: erik@foi.dk

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A FRAMEWORK FOR CAPACITY APPRAISAL IN FISHERIES

by

S. Pascoe, D. Gréboval and J.Kirkley

Abstract: *The need for effective management of fishing capacity has been highlighted in recent years following the realization that many of the world's major fishing resources are overexploited. In order to manage capacity, managers need to establish the current level of fishing capacity as well as the target, or desired level of fishing capacity. The latter will largely depend on the objectives of management, which may vary from fishery to fishery. In this paper, a framework for assessing the extent of overcapacity in fisheries is presented. The key concepts relating to capacity, capacity utilization and excess capacity in fisheries are also discussed.*

1. INTRODUCTION

In many parts of the world, fisheries are currently both biologically and economically overexploited. In Europe, reductions in Total Allowable Catches (TACs) in excess of 50 were imposed for many North Sea stocks in 2002, with most other stocks subject to TAC reductions of between 10 and 30 percent (DG Fish 2001). Further cuts in quotas were made in 2003. DG Fish (2000) estimate that, in 2000, there was more than 40 percent overcapacity in the EU fleet as a whole. In the USA, fifty-five percent of federally managed fisheries were found to be operating at unsustainable levels (Ward, Brainerd and Milazzo, 2001). A study of five federally managed fisheries estimated that there was around 50 percent overcapacity across the fisheries studies, although this varied from fishery to fishery (Kirkley *et al.,* 2002). Similar examples of excessive levels of fishing capacity are observed throughout the world. FAO (2000a) found that about 50 percent of world fisheries are fully exploited and are, therefore, producing catches that have either reached or are very close to their maximum limits, with no room expected for further expansion. Another 15 to 18 percent are overexploited and are in a state of decline. A further 10 percent of stocks have been depleted or are recovering from depletion.

As a result of the relatively poor state of many world fisheries, the effective management of fishing capacity has become a major issue internationally. In 1998, a technical working group was convened by the Food and Agriculture Organization of the United Nations (FAO) to consider the management of fishing capacity (FAO, 1998). Following this, FAO produced an International Plan of Action for the Measurement of Fishing Capacity (FAO, 1999), which requires participating countries to develop an efficient, equitable and transparent capacity management plans by no later that 2005. As part of the development of the capacity management plans, participating countries are required to undertake regular assessments of their existing levels of capacity, and identify which fisheries are in most need of capacity management.

The management of capacity requires several key elements – a means to assess the current level of capacity, a means to identify the desired level of capacity (i.e. target capacity), and a mechanism to move from the current situation to the desired situation. In 1999, FAO organized an international conference in Mexico to discuss methods for the measurement of fishing capacity (FAO, 2000b), while a further meeting was held in 2002 on the transition from overcapacity (Metzner and Ward, 2002).

The objective of this paper is to outline a framework for assessing current and target capacity in fisheries. The framework was developed in light of the FAO International Plan of Action (FAO, 1999). The first section will review the basic definitions underlying capacity estimation. A framework for assessing capacity is presented, involving monitoring and the estimation of current and target levels of capacity. A number of methods for estimating output-based measures of capacity are outlined, as are methods for identifying target levels of capacity.

2. DEFINITIONS AND PROBLEMS OF OVERCAPACITY AND CAPACITY UNDERUTILIZATION

In December 1999, a Technical Consultation on the Measurement of Fishing Capacity was held in Mexico City to define capacity and develop methods for measuring and assessing fishing capacity (FAO, 2000b). During the meeting, definitions of capacity were developed along with a range of methods for estimating capacity. Fishing capacity was subsequently defined as: *the amount of fish (or fishing effort) that can be produced over a period of time (e.g. a year or a fishing season) by a vessel or a fleet if fully utilized and for a given resource condition.* Full utilization in this context means normal, but unrestricted use, rather than some physical or engineering maximum.

From the above definition, capacity can be expressed in terms of inputs (e.g. potential fishing effort) or outputs (e.g. potential catch). These measures are not equivalent except under certain conditions that rarely hold in fisheries.[1]

A measure that has recently gained increase use in the fisheries literature is *capacity utilization* (see, for example, Dupont *et al.*, 2002; Felthoven, 2002; Vestergaard, Squires and Kirkley, 2003; Tingley, Pascoe and Mardle, 2003). This is primarily an output-based measure, determined as the ratio of the current to potential output under normal working conditions. A similar input based measure could be defined as the ratio of current fishing effort to potential fishing effort, again assuming normal working practices and given the state of the resource. The measure ranges from zero to one, with a value less than 1 indicating underutilization of the existing capacity (i.e. the current output is less than the potential output given the characteristics of the vessel and the state of the stocks).

Capacity underutilization is an indicator of potential future problems in the fishery. The existence of capacity underutilization may imply the existence of excess capacity.[2] That is, the existing level of capacity is greater than that required to harvest the resource at the current level. Both capacity utilization and excess capacity are short run concepts only, as under different circumstances (e.g. a recovered stock), the existing fleet size may be fully required to harvest the resource at the optimal level.

Changes in capacity utilization over time can provide information on the effectiveness of management in controlling fishing capacity. Declining capacity utilization may indicate that management is not constraining capacity growth, just its utilization. In contrast, increasing capacity utilization may indicate that capacity management is working

The concepts of capacity and capacity utilization relate to the existing condition of the resource. In the longer term, some other level of the resource may be desirable, particularly if the stock is currently overexploited. Associated with this desired stock level would be a desired level of output that would represent the sustainable yield that could be attained, and a desired fleet size/configuration that would take this sustainable yield at lowest cost. These desired long run levels of output and fleet size can be considered as measures of *target capacity*.

---

[1] Equivalence between input and output based measures of capacity requires the existence of a perfectly linear relationship between the level of inputs and the level of outputs (e.g. $C=qEB$). That is, doubling the level of all inputs would double the level of outputs. In most fisheries, this relationship is non-linear. In some cases, output may increase by a greater degree with an increase in inputs (increasing returns to scale), while in other cases output may increase by a smaller proportion than inputs (decreasing returns to scale). A good example illustrating the difference between input and output measures of capacity is given by Pascoe, Coglan and Mardle (2001).

[2] Capacity underutilization is not a reliable indicator of excess capacity, particularly if the underutilization is due to market forces as detailed below. Further, the existing level of inputs may be appropriate given higher stock levels. Removal of this 'excess capacity' might adversely affect the future productivity of the fishery if it is recovering. As a consequence, capacity utilization should only be used as a "rough" indicator of problems of excess capacity in fisheries.

A long-term output based measure of overcapacity would relate the potential output from the current fleet given the desired stock level to the target level,[3] while an input based measure would relate the level of investment in the fishery now (in terms of boat numbers, GRT or some other unit) with the desired level of investment.

This latter measure is generally termed *overcapitalization*, and can be illustrated in Figure 1, which uses a simple Schaefer model indicating the relationship between sustainable yield and fishing effort (defined in terms of fleet size). From this figure, the current fleet size, F, is producing a current level of output, O. In contrast, a greater yield O_{msy} can be achieved with a smaller fleet size F_{msy}. The difference between the current fleet and target fleet is the level of excess capital, and is a measure of the level of overcapitalization of the fishery. The actual target level of output will depend on the management objectives for the fishery. In some cases, maximum sustainable yield may be the target level of output while in others maximum economic yield may be more appropriate.

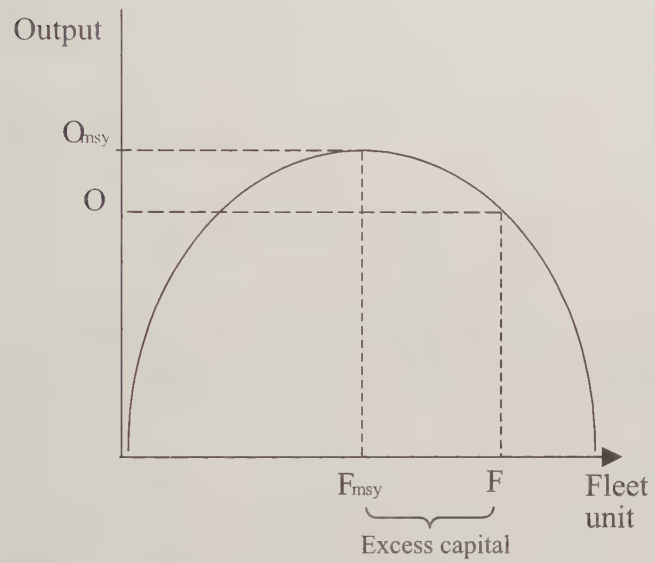

Figure 1. Overcapitalization in fisheries

In summary, capacity and capacity utilization are short-term concepts that relate to the ability of the existing fleet to increase their output given current conditions. In contrast, overcapacity and overcapitalization are longer-term concepts that indicate the extent to which the current fleet may need to be reduced in order to achieve a long run target level of output.

2.1 Causes and problems of capacity underutilization

Capacity underutilization may occur for several reasons. First, management induced capacity underutilization can occur if the fishery output is constrained, such as by a total allowable catch (TAC) limit or as a result of a restriction in the number of days that can be fished (e.g. seasonal closures, days-at-sea limits). Second, capacity underutilization may occur as a result of adverse market conditions. For example, if the price of fuel increased or the price of fish decreased, the profitability from fishing would decrease and this may cause some (less efficient) operators to fish less than they might otherwise fish.

Market induced capacity underutilization is not of concern to fisheries management as the individual fisher is operating in a rational manner. In many cases, market induced capacity utilization is self adjusting, as either prices (costs) will rise (fall) to their original levels, or less efficient vessels who cannot operate under these new market conditions will seek to exit the fishery. Management induced capacity underutilization, however, can have implications for the effective management of the fishery.

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[3] A short run equivalent measure of overcapacity could also be the ratio of the current potential catch to some target catch in the current period (e.g. a TAC). This may be an unreliable indicator of overcapacity if a TAC has been set at a low level to allow the stock to recover.

From a pure stock conservation perspective, the existence of management induced capacity underutilization does not pose any threat provided that the total output of the fishery is constrained to a sustainable level (e.g. through an enforced total allowable catch (TAC) quota). However, the existence of underutilized capacity creates a number of economic problems, some of which may also have implications for the success of the stock conservation measures. These include economic incentives to exceed any quota imposed, as well as incentives to race to fish, and to increase capitalization in a bid to increase individual returns.

At the aggregate fishery level, the existence of underutilized capacity indicates a waste of resources, as, by definition, the same catch could have been taken with fewer boats operating at full capacity. The additional vessels are therefore not adding any additional value to the industry, and are therefore redundant. The costs incurred by these vessels directly reflects the economic cost to the industry (and society as a whole) of the excess capacity.

As well as imposing a direct economic cost on the industry, the existence of underutilized capacity can produce other incentives that are detrimental to both the stock and the longer-term profitability of the industry. When the harvesting capability of the fishing fleet exceeds the available catch, incentives are generated to increase investment in the industry in a bid to get a larger share of the catch. This may take the form of a larger boat and/or a larger engine, and the use of more fishing gear in order to maximize the individual catch. In the short term, undertaking such investment is likely to increase the profitability of the investor. However, in the longer term other fishers will be forced to either increase their investment to increase their (now reduced) share of the catch or exit the fishery. As a consequence, the "race for fish" arising from the existence of excess capacity may result in further increases in excess capacity, with detrimental effects on both the stock and profitability of the fishery as a whole. This problem was typified by the pacific halibut fishery, where the existence of excess capacity resulted in even greater levels of capacity entering the fishery (see Homans and Wilen, 1997 for an illustration of this).

The alternative to increasing investment to maintain catch shares under such a scenario is to exit the fishery. However, the lack of alternative uses of fishing vessels makes exiting the fishery difficult. If the revenue from the restricted level of catch is not sufficient to cover the vessel costs, incentives can be created to exceed any quota imposed. The actual extent of illegal landings will depend on the level of surveillance and expected fines or penalties, but it is likely that levels of illegal landings will be correlated with the level of excess capacity.

A related problem that can result in apparent capacity underutilization is the existence of part time fishers. These vessels will be identified as underutilized when compared with full time vessels, but their potential to increase their level of fishing activity may be limited while they remain in the control of the current owners. However, as it is possible for these owners to change their operation to full time, or to sell the vessel to a new fisher who would use it on a full time basis, it is appropriate to treat these as vessels as having underutilized capacity for the purposes of capacity management.

In summary, the existence of underutilized capacity imposes direct costs on the industry through forgone economic profits, and indirect costs through the incentives created to increase investment (and thereby further increase excess capacity) and increase illegal landings.

2.2 Causes and problems of overcapitalization

The existence of overcapitalization is often attributed to the lack of property rights in fisheries. Without well defined property rights, individuals will increase their effort, and in fisheries without license limitations, new fishers will enter, provided that greater profits can be earned in the fishery than in other industries or activities. As a consequence, the resource rent (the implicit total value of the resource used in the production process) is dissipated. Further, depending on the actual harvest costs, the level of investment in the fishery can exceed that required to harvest the resource at its greatest productivity level (e.g. maximum sustainable yield), and also the level required to harvest the resource to achieve its greatest economic value to society (maximum economic yield).

A major problem with overcapitalization is the loss of potential resource rent that could be obtained from the fishery. This rent could be returned to the local community to improve local facilities, or retained by the fishers in the form of increased profitability. The loss of this rent therefore leads to lower incomes of the fishers and their crew, which can lead to lower incomes in the regional as a whole through reduced use of local services.

Overcapitalization is also generally associated with lower levels of output, which may have effects on processing and retail sector performance. Excessive levels of overcapitalization can result in stock collapse.

2.3 Input versus output based measures of capacity

Management of fishing capacity requires some estimate of the existing level of fishing capacity in a fleet and the corresponding level of excess capacity in the fishery. To this end, many countries have developed a range of capacity indicators, mostly based on physical attributes of the fleet (FAO, 2000). Key indicators of capacity applied in many countries are measures such as gross tonnage (a measure of the volume of the vessel), engine power, and the number of boats. In some countries, engineering measures such as vessel capacity units,[4] generally based on a combination of characteristics, have also been developed. More recently, output based measures of capacity have been developed that relate to the potential level of output of a fleet.

Input based measures of capacity involve an implicit assumption that the level of output is related to the level of physical inputs employed in the fishery. If these inputs were fully utilized, then the capacity of the fleet would be a function of these inputs. The level of utilization in this case would relate to the level of activity (e.g. days fished). Hence, the capacity of the fleet is related to the fixed inputs employed, e.g. capacity = f (boat size, engine power, etc.) on the assumption that they are fully utilized. As a consequence, changes in effort levels do not change the *potential* output of the fleet, so do not directly affect the capacity (just capacity utilization).

The link between the level of inputs and the level of outputs is generally the basis for management of fisheries using input controls. Changing the level of inputs (e.g. though decommissioning) or their utilization (e.g. through days at sea restrictions, seasonal closures), is assumed to have a proportional effect on the level of output. However, as noted previously, this assumes that the fisheries are subject to constant returns to scale. Several studies (e.g. Pascoe and Coglan, 2000; Pascoe, Coglan and Mardle, 2001) have demonstrated that input measures are often not equivalent to output measures of capacity, and changes in the distribution of the inputs can have a substantial effect on the output in a fishery even if the total input-based "capacity" is unchanged.

Output based measures of capacity attempt to measure the potential output and/or the level of capacity utilization directly, usually at the individual vessel level. Implicit in the estimation of the output based capacity measure is also a relationship between the level of fixed inputs, their level of utilization and the level of output. However, the methods for estimation do not generally impose the same

[4] For example, the UK defines vessel capacity units (VCUs) as: $VCU = length*breadth + 0.45*kw$. VCUs are used as the basis for capacity management in the UK, including decommissioning.

assumptions that are implicit in the input based measures. As a result, the measures are not affected by the distribution of inputs.

While providing a better estimate of capacity and capacity utilization in fisheries (FAO, 2000), the output-based measures are not as useful for the purposes of management. As noted above, most fisheries are managed using some form of input control. In order to reduce capacity under such a management system, inputs need to be withdrawn so some input based measure is necessary. Consequently, there is a need for both types of measures in fisheries management; with identification of the relationship between the different measures an important component of the management information system.

3. CAPACITY ASSESSMENT FRAMEWORK

The capacity assessment framework is illustrated in Figure 2. An overriding activity that is required for any capacity assessment is a monitoring program to collect appropriate data for any subsequent analysis. Given the existence of appropriate data, capacity appraisal involves the estimation of the current level of capacity and capacity utilization, the assessment of target capacity levels, and the potential fleet reduction, if any, that is required to achieve the target capacity levels.

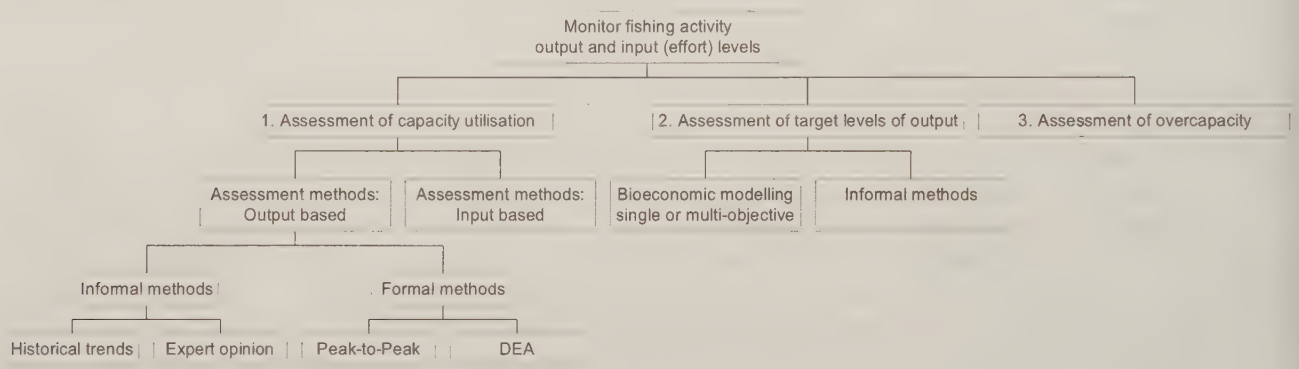

Figure 2. The capacity assessment framework

The process of assessing current and target capacity can be either formal (i.e. using a quantitative modelling approach) or informal. Examples of these approaches are outlined in the following sections.

3.1 Monitoring and data needs

The data requirements for capacity assessment are no different to those that are required for the effective management of a fishery, and are routinely collected in many countries already.[5]

3.1.1 Input data

Input data are required for the estimation of both input and output measures of fishing capacity. Input data can be divided into two main types: measures of physical capacity and levels of activity. Measures of physical capacity provide, as the name suggests, an immediate input-based measure of capacity. Measures include, for example, total boat numbers, engine power (e.g. kW or Horsepower), length, and Gross Registered Tonnage (GRT). In most fisheries, it is possible to identify several different fleet segments (e.g. defined by different gear types, target species or fishing location), and vessels can be allocated to these fleet segments where possible.[6] In order to estimate appropriate output-based measures of capacity, the vessel information ideally should be collected at the

[5] While data collection occurs in most countries, the level and type of data may vary. This can affect the range of capacity measurement options that can be applied.

[6] This becomes complicated in fisheries where the vessels are multipurpose, and may operate using several gear types over the year.

individual boat level. Input based measures, however, can be derived from totals for the fleet segments (e.g. total GRT, engine power) if individual data are not retained.

Fishing activity information includes days/hours fished as well as the quantity of gear used (e.g. km nets, number of traps). Again, this is required at the individual vessel level for output-based measures. It is also useful to have this information at the boat level in order to estimate potential fishing effort (an input based measure).

3.1.2 Output data

Output data are ideally required at the level of the vessel, and also disaggregated into species. This information is collected in many countries already through vessel logbooks, and is used for monitoring landings.

3.1.3 Economic data

Economic data are required for the assessment of target capacity,[7] but provide useful information on the status of the fishery in their own right. Key economic information that is required includes the price of each species, and the costs and earnings of the individual fishing boats. The key cost information required includes a measure of the running costs (e.g. fuel, ice, bait), crew costs, annual fixed costs (e.g. harbour dues, administration costs, licence fees, maintenance) and capital costs (e.g. value of the boat and gear).

3.2 Estimation of capacity and capacity utilization

The estimation of input-based measures capacity and capacity utilization is relatively straight forward as the information collected on the physical attributes of the fleet forms the measures directly. This section will therefore focus on estimation of output-based measures. Depending on the degree of data availability, either informal or formal methods of assessment may be appropriate.

Informal methods of estimation of capacity utilization and capacity output can include an examination of historical trends or the use of expert advice. Examination of catch per vessel over time can provide a crude measure of how much an individual vessel could catch. The highest observed catch rate can form a measure of capacity output, and hence capacity utilization is the ratio of the current output to that capacity output. However, this ignores changes in stock conditions and also possible changes in technology that could have affected the catch rate over time. Similarly, economic conditions (e.g. prices and cost changes) may affect output levels and subsequently distort perceptions about capacity levels.

Discussion with fisheries experts could also provide estimates of capacity output. These experts may include scientists (including economists), engineers and/or industry members. Based on their experience, they could provide estimates of how much different types of vessel would be able to catch if fully utilized given the current stock conditions. This information may be collected either on an ad hoc basis (e.g. through discussion with key players in the fishery), or systematically through some form of survey of industry members. Other formal mechanisms for extracting information from experts include the Delphi Technique, which is an iterative process involving collecting opinions from a group of experts, feeding back the compiled information to the group and then eliciting modified opinions. The process is repeated until the group reaches a final consensus.

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[7] Economic information can also be used for the estimation of capacity utilization directly. Incorporation of cost and price information into the capacity utilization provides an economically efficient measure of capacity output rather than just a technically efficiency measure of capacity (see Pascoe and Tingley, 2003 for an example).

More formal methods for estimation capacity and capacity utilization also exist. The most frequently applied to the estimation of capacity in fisheries has been peak-to-peak analysis and data envelopment analysis (DEA).[8]

3.2.1 Peak-to-peak analysis

A key advantage of peak-to-peak analysis relative to other methods for estimating capacity utilization is that it requires minimal data. Peak-to-peak estimates of capacity and capacity utilization are estimated at the fishery level, so require information on only total fishery output and the level of physical inputs.[9] Catch per unit of physical inputs are estimated, and it is assumed that peak output levels indicate full capacity utilization, and lower levels indicate capacity underutilization.

Changes in peak catch rates are assumed to be due to technological change. The average rate of technical change is applied to derive a full capacity rate. Capacity output is estimated by multiplying the capacity rate by the number of fishing units. Given capacity output, capacity utilization can be derived.

This can be illustrated with a simple example using data from the Dunganess crab fishery in the US (Table 1 and Figure 3).[10] The peak catch rates were observed in 1959 and 1968. Average technical change between these periods was subsequent estimated 10.79 (i.e. (520.4-423.3)/9, the trend indicated in Figure 3). This technical change rate was used to derive the capacity catch rate – the catch rate if boats were operating at full capacity. For example, the capacity rate in 1960 was estimated as the catch rate in 1959 (assumed to be equivalent to the capacity rate) plus 10.79. The potential catch was estimated by multiplying the capacity catch rate by the number of boats. Capacity utilization can then be estimated by dividing the current catch by the capacity catch. From Table 1 and Figure 3, the fishery was subject to long periods of low capacity utilization.

Table 1. Example: Peak-to-peak analysis of the Dungeness crab fishery
Source Kirkley and Squires (1999)

Year	Catch	Boats	Catch rate	Capacity rate	Potential catch	Capacity utilization
1959	36.95	87.3	**423.3**	423.3	37.0	100.0%
1960	36.16	92.3	391.8	434.0	40.1	90.3%
1961	32.7	90.55	361.1	444.8	40.3	81.2%
1962	23.36	88.01	265.4	455.6	40.1	58.3%
1963	24.86	87.49	284.1	466.4	40.8	60.9%
1964	23.04	90.82	253.7	477.2	43.3	53.2%
1965	28.91	100.36	288.1	488.0	49.0	59.0%
1966	39.72	93.91	423.0	498.8	46.8	84.8%
1967	42.44	91.7	462.8	509.6	46.7	90.8%
1968	49.97	96.03	**520.4**	520.4	50.0	100.0%
1969	48.06	122.44	392.5	531.1	65.0	73.9%
1970	58.51	130.08	449.8	541.9	70.5	83.0%
1971	41.61	157.43	264.3	552.7	87.0	47.8%
1972	28.25	179.52	157.4	563.5	101.2	27.9%
1973	14.37	171.45	83.8	574.3	98.5	14.6%

[8] Other methods are also available, including the use of stochastic production frontiers. A detailed overview of methods available for estimating capacity and capacity utilization is given by Kirkley and Squires (1999) and Pascoe *et al.* (2003).

[9] Peak-to-peak estimates can also be made at the species level.

[10] Data for this example were taken from Kirkley and Squires (1999). Other examples of the technique are presented by Hsu (1999).

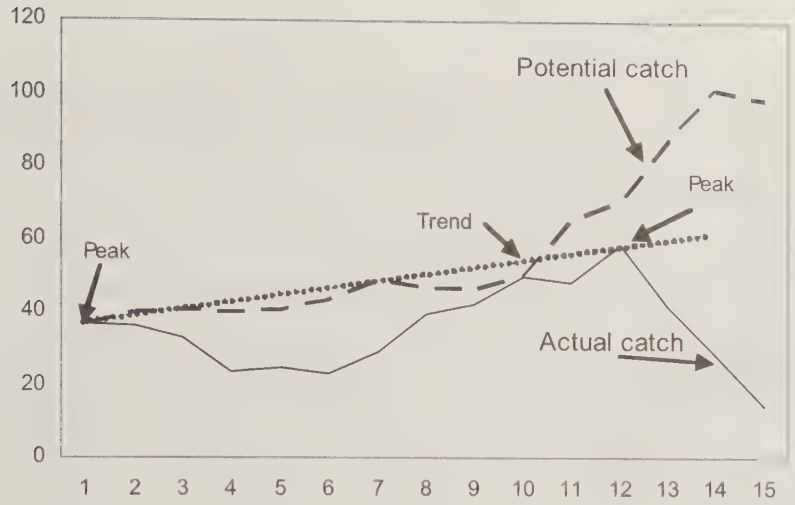

Figure 3. Peak-to-peak analysis of the Dungeness crab fishery

The key advantages of the method are its simplicity and relatively low data requirements. However, the method has a number of problems that need to be considered. Firstly, in multispecies fisheries, analysis of capacity utilization at the species level may become problematic if fishers are able to target individual species and effort is switched between species. In such cases, there is the potential for "underutilization" to appear as a result of switching between species. In some cases, it may appear that all species are underutilized when considered separately, even though the fleet may be fully utilized. Consequently, interpretation of the results needs to take into consideration the characteristics of the fishery to ensure that underutilization is not overestimated, and may need to be supplemented with expert opinion.

The method also ignores changes in stock conditions. Lower catch rates in some years could indicate smaller stocks rather than underutilization of boats. Conversely, peak catch rates may coincide with above average stock levels. Actual capacity utilization may be high in the intermediate (normal stock condition) periods, although will appear low if the peak periods are affected by above average stock levels. This is particularly a problem if stocks are highly variable, such as often occurs with small pelagics (e.g. sardines, anchovies). In the case of the Dungeness crab example above, the low capacity utilization in the last four or five years most likely represented a decline in the stock rather than capacity underutilization per se. As a consequence, the interpretation of the results needs to consider these factors.

3.2.2 Data Envelopment Analysis (DEA)

DEA is an output-based measure that can provide information on both a species by species basis as well as a fleet segment basis. Estimates of capacity and capacity utilization can be made at the fleet level directly, or, preferably, at the individual vessel level and aggregated up to the fleet level.

DEA is a "frontier" based method: the outputs of individual boats in the fleet are compared, with the "best" set of vessels used as a benchmark. The "best" boats are those that have the greatest level of output per unit of input. These boats determine the "frontier". For example, in Figure 4, the two axes represent the average catch per unit input (e.g. kg/GRT) of two species. The points *A, B, C* and *D* represent the catch composition of four boats. These boats define the frontier as no other boats have greater catches per unit input. Point *E* represents a boat with a lower catch per unit input of both

species. If the boat was operating at the same level as the other vessels, it could potentially catch more of each species. Based on the catches of the other vessels, the boat at point *E* could potentially operate at point *E**. This latter point defines the capacity output of the boat at point *E**, and the ratio of the distances *OE/OE** is a measure of its capacity utilization.[11]

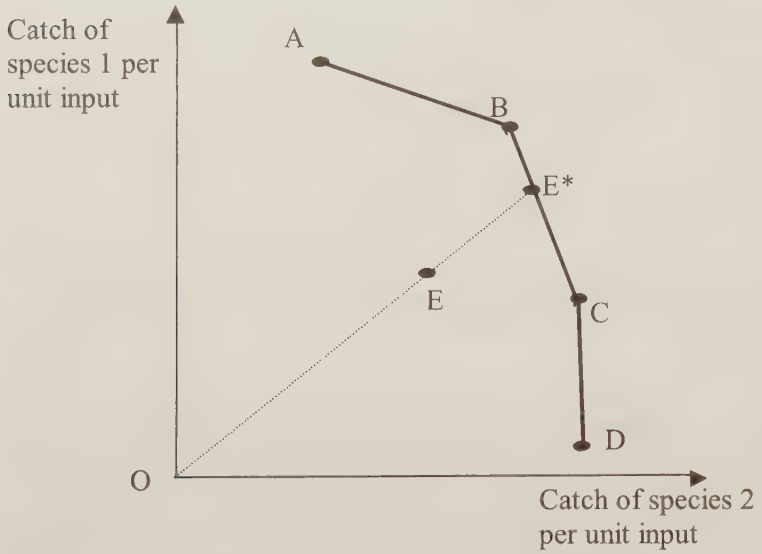

Figure 4. Two-output production possibility frontier

DEA is a non-parametric technique, solved using a linear programming model, so cannot directly deal with random error (e.g. "luck" in terms of catch). However, the method that has been developed and applied in fisheries is not affected by random error,[12] making it suitable for use in even highly variable fisheries.

The Technical Consultation on the Measurement of Fishing Capacity (FAO, 2000) suggested that DEA is the preferred method for estimating capacity and capacity utilization in fisheries as it can directly accommodate multiple inputs (e.g. boat size, engine power, gear and area fished) and multiple outputs (i.e. catches of different species). Hence, it can be used for multispecies fisheries without the problems experienced using peak-to-peak. Further, capacity utilization is assessed in each time period separately, so is not affected by stock fluctuations. Industry capacity can be estimated as the sum of the individual capacity output levels, although this is an underestimate of the actual industry capacity output level as it may be possible for higher catches to be realized through a different allocation of inputs.

3.3 Assessment of target capacity

The management of fishing capacity requires not only some measure of the existing level of fishing capacity, but also some measure of the desired level of capacity. A wide range of sustainable yields can be achieved in a fishery. Indeed, even an overcapitalized fishery, as illustrated in Figure 1, can produce a sustainable yield that may be considered "optimal" under some circumstances. The target capacity therefore relates to the objectives of management, and the "optimal" yield is that which best achieves these objectives. In fisheries where employment is considered a key consideration, lower yields and total profit levels may be considered an acceptable trade-off. Conversely, in industrial fisheries, resource rent generation may be considered of greater importance, accompanied by higher yields but lower employment levels. Hence, the maximum economic yield may be an appropriate

[11] Technical efficiency is also estimated in a similar way, with variable inputs also considered in the analysis. The estimation of capacity utilization used information only on fixed inputs.

[12] Details on the equations underlying the DEA methodology are given in Kirkley and Squires (1999) and Pascoe *et al.* (2003). See Holland and Lee (2002) for details on the sensitivity of the results to random variation.

target output capacity. Where the fishery is a main provider of food and imports are prohibitively expensive, the maximum sustainable yield (MSY) may be considered the target output level.

In fisheries managed through input controls, the assessment of target levels of capacity requires estimates both in terms of outputs and inputs.[13] For example, if the objective of fisheries management was to maximize the sustainable yield, then both the output at MSY and the fleet size/configuration required to achieve it need to be estimated.

The estimation of the "optimal" yield can be undertaken either through a formal assessment using some form of model when sufficient data are available, or informally through the use of reference points/periods when data are limited.

3.3.1 Informal approaches

As with the estimation of current capacity, expert opinion can be used to derive a "rough" estimate of the target level of capacity.[14] This may involve consideration of the output and input levels in the fishery when it was believed to be operating at a sustainable and optimal level. Similarly, the average output over an extended period of time may be considered as an initial indicator of the target yield in the absence of more appropriate information.

3.3.2 Formal approaches

Stock assessment techniques are well established that allow for the estimation of sustainable yields in fisheries, provided sufficient data are available to estimate the required model parameters. These models are sufficient to estimate both target output capacity and input levels provided biological sustainability is the only objective of management.

Where other factors are considered important, such as incomes and employment for example, some form of bioeconomic model is required. Optimization model can be used to estimate the optimum yield and fleet size that are both sustainable and also improve fisher incomes. Multi-objective models can be developed that allow the "optimal" to be defined in terms of several criteria (e.g. employment, profitability).[15]

Bioeconomic models are particularly useful for the analysis of optimal fishing capacity in multi-species, multi-gear and multipurpose fisheries. To determine the optimal target capacity, consideration needs to be given to all activities undertaken by the vessels. The overall optimal level of output of any species may not be optimal for each species individually. That is, the optimal fleet size for the fishery as a whole may result in some species being harvested at beyond their individual optimal level, while others harvested below their individual optimal level. These synergistic effects cannot be adequately addressed solely in biological models. Costs and revenues, and the technical interactions that may exist between the species given the gears employed, affect the behaviour of fishers, and subsequently the distribution of fishing activity in response to any management change.

The use of any model – biological or bioeconomic – for the purposes of estimated target capacity, however, requires some caution. There is generally considerable uncertainty about many of the biological and economic parameters that are used in these models. As a consequence, the results need

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[13] This is also true for fisheries managed using a combination of input controls and aggregate output controls (e.g. TACs) as the main mechanism for capacity management will still involve the use if input controls (e.g. decommissioning schemes). The only management system in which just an output-based measure of target capacity may be appropriate is a system of individual transferable quotas.

[14] The more formalized Delphi technique could again be applied to extract the information from the experts, as could other elicitation techniques such as the Analytical Hierarchy Process (AHP) (Saaty 1977). The latter process has been used successfully in other areas to derive reliable estimates of unknown parameters. See Zuboy (1981) for a fisheries-specific example of the Delphi technique, while Mardle and Pascoe (1999) provide examples of AHP applied to fisheries.

[15] A detailed review of the use of multi-objective models in fisheries is given by Mardle and Pascoe (1999).

to be considered as indicative rather than prescriptive. That is, they can act as a guide, but should not be used as a recipe for capacity management.

3.4 Capacity appraisal

The process of capacity appraisal involves both qualitative and quantitative approaches based on the analyses undertaken and knowledge of the fishery. The principle objective of capacity appraisal is to identify how much overcapacity exists, if any, and also where the overcapacity may exist. For example, are all fleet segments in a fishery overcapacity or just some? Can fleet reduction reduce overcapacity on all species or does an "optimal" fleet involve some overcapacity still for some species?

The estimates of capacity utilization provide a short-term indicator to the existence of overcapacity in a fishery. However, the appraisal needs to take into consideration a range of other factors. For example, in highly fluctuating stocks, some degree of capacity underutilization may be required in an average (or poor) year in order to allow sufficient capacity in the fishery to take advantage of a good year. Similarly, if capacity underutilization is a result of temporary adverse market conditions, then under more normal conditions the fleet may be operating at full capacity. Finally, if capacity underutilization is the result of management interventions (e.g. a restriction on the number of days that can be fished) with the aim of allowing the stock to recover, then the existing fleet may operate at full capacity once the stock has recovered and the restrictions removed. Consequently, the interpretation of capacity underutilization needs to be made in the broader context of information on what is happening in the fishery.

Deriving output-based measures of overcapacity is considerably more complex than input based measures. It is not appropriate to compare the existing capacity to the optimal capacity estimated using bioeconomic models in order to derive a longer-term measure of overcapacity. For example, a fleet may be operating at full capacity in a depleted fishery and producing an output less than the long-term target output, but that same fleet, if operating under conditions of stock recovery could produce an output well in excess of the target output. As a result, in order to estimate the extent of any overcapacity, the models developed above need also to be used to estimate the capacity output of the existing fleet under the long-term stock conditions (i.e. when the stock has recovered). This is illustrated in Figure 5, where the current fleet has a capacity output O under current stock conditions, but could catch O* if the stocks were at the level that could produce maximum sustainable yield.

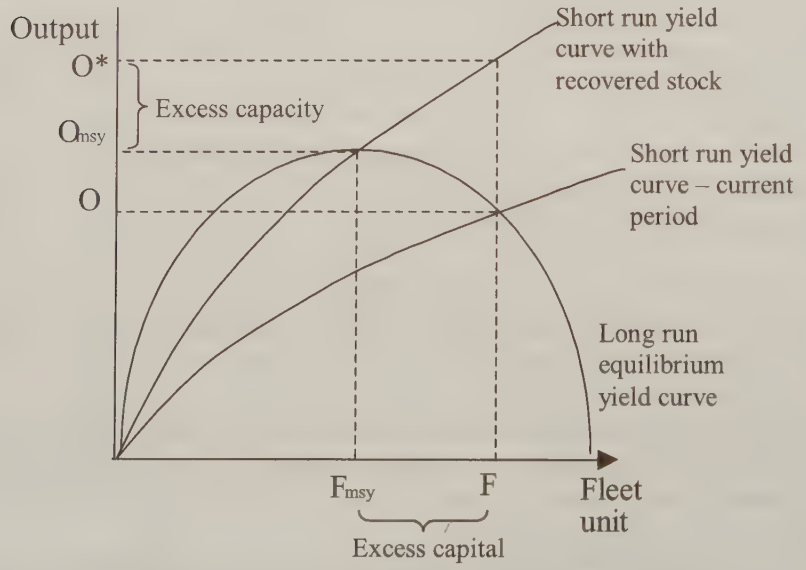

Figure 5. Estimation of overcapacity in the longer term

In contrast, the level of excess capital can be more easily estimated using bioeconomic (or biological) models, as the difference between the current fleet size and the "optimal" fleet size.

4. SUMMARY AND CONCLUSIONS

The capacity appraisal framework can be summarized as consisting of four main steps. Essential to any capacity management program, and indeed any fisheries management, is the monitoring of the current level of exploitation. This involves collecting information on the vessels that are operating in the fishery, their level of activity and their level of output. These data can then be used to estimate the level of capacity utilization to provide a short-run indicator of where problems may exist in different fisheries and fleet segments.

The data can also be used to develop models of the fisheries in order to estimate target levels of capacity. The "optimal" level of capacity will depend on the objectives of management.

In some cases, data will not be available in order to either assess capacity utilization or develop models for assessing target levels of capacity. In such cases, expert opinion can be used to derive estimates as an interim measure while data are being developed for more formal assessments. Lack of data should not be considered a valid reason to ignore potential problems in fisheries, particularly as they can result in greater problems in the longer term if not addressed.

The final capacity appraisal process involves using the information developed in the previous steps to determine the extent of any overcapacity in a fishery. As the methods outlined previously provide indicators only, any appraisal of overcapacity needs to take into consideration the assumptions underlying the formal analysis.

The capacity appraisal framework does not provide information on how target capacity levels can be achieved. Management plans need to be developed and implemented that will move the fishery from the current situation to that identified as the target. This in itself will present difficulties, as capacity reduction plans may be unpopular with the industry, which may create challenges in its implementation. FAO have recently held an Expert Consultation on Catalysing the Transition away from Overcapacity in Marine Fisheries (Metzner and Ward, 2002) to address these issues.

The purpose in this paper was to present an overview of the capacity appraisal framework. The methods for capacity assessment have only been briefly summarized in this paper. The estimation of output based measures of capacity and capacity utilization in fisheries is still relatively new, and now doubt will continue to evolve in the future. In contrast, the development and application of bioeconomic models has been well established, although the use of these models for the capacity appraisal has also been limited. The need to effectively assess and manage capacity, however, is going to stimulate increased research efforts in these areas in most countries over the coming years.

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MEASURING CAPACITY IN FISHERIES: ANALYTICAL TOOLS AND DATA AGGREGATION

by

E. Lindebo[1]

Abstract: *An array of approaches to capacity analysis is cited in the research literature, which has been given specific attention by FAO in recent years. What appears to be lacking is the practical and illustrative application of these analyses in an empirical setting for the fishing industry. Capacity analysis can assist fisheries managers in obtaining more information on the underlying capacity issues of fishing fleets, in terms of efficiency, productivity and overall balance with available resources. Many tools are available that can be readily applied to input/output data of fishing fleets. In this paper five such approaches are considered in the context of economic theory, namely catch-per-unit-effort, variable input utilization, peak-to-peak, data envelopment analysis and break-even analysis. The tools are applied to aggregated European trawler fleet data and disaggregated Danish vessel data, Results are compared and contrasted, and a range of issues that should be considered when applying capacity analysis to fisheries concludes the paper.*

1. INTRODUCTION

The issue of fishing capacity has been at the forefront of fisheries management concerns in recent years. The Food and Agriculture Organization of the United Nations (FAO) International Plan of Action for the Management of Fishing Capacity adopted in 1999 calls for member countries to provide preliminary assessments of the capacity situation in all principal fisheries (Cunningham and Gréboval, 2001). It is considered that this kind of information would allow the identification of fisheries and fleets where there may be an imbalance between capacity and resources. An array of approaches to capacity analysis is cited in the research literature, which has been given specific attention by the FAO. What appears to be lacking, however, is the practical and illustrative application of these analyses in an empirical setting for the fishing industry. It is felt to be of the up-most importance to help illustrate the application of the various approaches to real data if managers are to make true inroads with capacity analysis.

In relation to available resources, the size of fishing fleets of European Union (EU) member countries is in excess of what is ultimately desired from both biological and socio-economic standpoints. Not only does the current situation lead to continued pressure on fishing stocks, but the overcapitalised nature of fleets and underutilization of fishing capacity also represent an economic waste to society. The continuation of financial aid to the industry is a further indication of lacking economic efficiency, as well as the undesired use of public finances. In 2001-02, the European Commission initiated a reform of the Common Fisheries Policy (CFP)[2] in order to address the current problems of EU fisheries management[3]. The end product was a string of Council Regulations[4] aiming to ensure the conservation and sustainable exploitation of fisheries resources, specifically addressing structural assistance and emergency measures for the scrapping of fishing vessels. The major framework of the reformed CFP now in force builds on multi-annual management plans, fishing mortality reduction,

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[2] The CFP is defined by Article 39 of the Treaty of Rome and Council Regulation (EEC) No 170/83 of 25 January 1983.

[3] A review of the CFP reform proposals and accompanying capacity policies can be found in Lindebo, Frost and Løkkegaard (2002).

[4] Council Regulations (EC) No 2369/2002, 2370/2002 and 2371/2002.

and capacity reference levels[5], the latter being implemented following the abolishment of capacity adjustment through the multi-annual guidance programmes (MAGPs). The reform also outlines the proposal for a scientific peer review of sustainable fish exploitation, with the intention of assessing the success of fishing mortality reductions in relation to fleet capacity during 2003-06. It should thus be regarded as a minimal requirement of a scientific peer review of fleet and resource balance in EU fisheries, for example, to undertake some form of analysis based on the approaches outlined in this paper.

Kirkley and Squires (1999) were among the first to seriously consider the issue of capacity in fishing industries in an analytical framework. In order to strengthen a peer review process, Lindebo, Frost and Løkkegaard (2002) and Lindebo (2003) extend this work to the European setting and discuss feasible options for capacity analysis that should help clarify the current capacity situation. These include the use of Data Envelopment Analysis and Break Even revenue estimations. This paper will elaborate on these ideas and apply these methodologies to aggregated European fleet data and disaggregated Danish vessel data. The paper will also consider the use of capacity analyses such as catch per unit of effort (CPUE), variable input utilization and peak-to-peak. The primary objective is thus to assess these methodologies in relation to available fleet data of variable aggregation, and identify obstacles that may complicate the application of such analyses in a management-oriented framework.

The results of the aggregated data analysis stated herein may not represent an accurate portrayal of the capacity situation in European fisheries, since a direct comparison between national fleet segments is not always feasible (due to multiple species, specific fishery characteristics, management differences, etc.). Kirkley and Squires (1988) indicate, for example, that capital inputs in fisheries are usually quite heterogeneous and cannot be easily aggregated without restrictive assumptions about the form of the catch equation or fisher behaviour. The use of aggregated data, at the global EU and FAO levels rather than at the national level, thus imposes restrictions on such analyses and asks the question whether it is a realistic approach to analysing capacity. Further, aggregated data also tends to lower capacity estimates. It needs to be acknowledged, however, that managers possess this kind of data, and hence it would be beneficial to identify the feasibility of applying aggregated data in an analytical setting.

The paper is structured as follows. Firstly, the notion of capacity in fisheries is discussed from input and output perspectives. An illustrative and practical outline of the abovementioned analytical tools is then given. The aggregated and disaggregated data analyses are considered and results are discussed. The paper concludes with an examination of the analytical tools and data aggregation implications with regard to current demands of capacity analysis in Europe and elsewhere.

2. CAPACITY IN FISHERIES

Capacity has mostly been defined as an input of fish production by fisheries managers. In most traditional industries this is simply measured as capital or employment. In the fisheries case, capacity has often been measured in terms of vessel number, vessel tonnage, engine power and days at sea, and represent a pseudonym of variable costs of fishing operations. Kendrick (1961) and Kirkley and Squires (1988) demonstrate that the number of vessels is an inadequate measure of the capital stock or investment, since few fleets have identical-sized vessels, characteristics or gear. Hence, if vessel numbers are to be aggregated then some determination of weights will be necessary. Also, the ability of a vessel to catch fish is a highly complex concept and depends on multiple inputs. Vessel tonnage (GT) and engine power (kW) have served as the capacity (input) indicators of EU fleets under MAGPs since 1983. Although these indicators will significantly impact a vessel's catching ability, and monitoring of these inputs may provide a simple indicator of capacity, it should be acknowledged that other inputs that are not monitored might allow an increase in effective capacity. It also relates more to capital utilization. According to Berndt and Morrison (1981) capacity utilization and capital utilization are equivalent only when (i) there is a single homogeneous capital stock, (ii) all variable inputs are in fixed proportions to the capital stock and each other, and (iii) there is constant return to scale. In fisheries, a constant return to scale is also required.

[5] Based on fleet capacity levels (GT and kW) of fishing fleets at the end of 2002.

In order to analyse the impact on fishing fleets in relation to fishing mortality reductions it may be helpful to consider capacity indicators related to economic theory, where capacity is defined as an output of production (FAO, 1998). These may provide administrators with information on fleet productivity and efficiency in given fisheries. It is interesting to consider various approaches to capacity since the perceptions of what constitutes capacity vary considerably among stakeholders. Capacity indicators may be in physical catch terms, as is most often applied to fishery analysis given the constraints of economic data availability. Such indicators include catch per unit of effort, the utilization of variable inputs (e.g. days at sea), the changes in catch rate relative to average technology trends, and the level of capacity utilization compared to "best practice" input/output combination vessels. If information on catch value is available these approaches may also allow for simplistic economic interpretations.

Alternatively, if economic cost/revenue data are available, a break-even revenue approach can be indicative of over-/undercapacity in a pure economic sense, based on the relationship between short run gross cash flow and fixed costs (as considered in Section 2.5). Capacity can be thought of as a concept strictly built on and fixed costs (as considered in Section 2.5). Capacity can be thought of as a concept strictly built on economic foundations. Klein (1960), Berndt and Morrison (1981), and Coelli, Grifell-Tatje and Perelman (2001) consider approaches that include long-run equilibrium with respect to the use of capital, short run cost minimization, and short run profit maximization, respectively (cf. Figure 1). If economic data are available, the Berndt and Morrison (1981) approach can be used, with the break-even approach offering a more simple and quick estimation. An economic approach can potentially provide more reliable information as it explicitly determines the output level consistent with the behaviour of fishing operators (FAO, 2000).

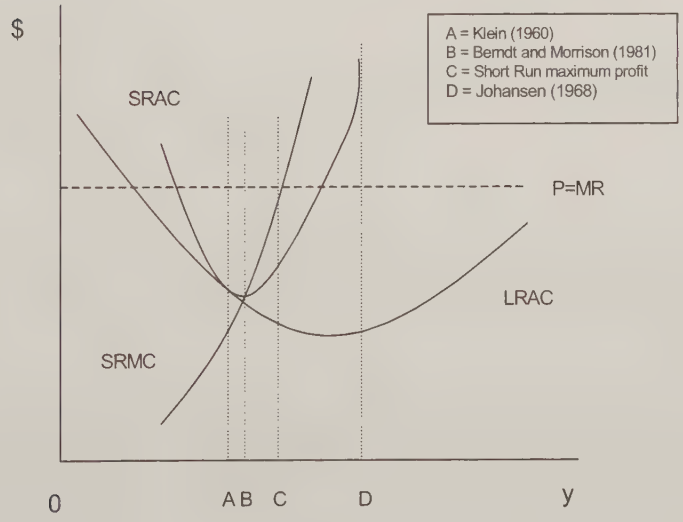

Figure 1: Measures of capacity (Coelli, Griffell-Tatje and Perelman, 2001)

Kirkley and Squires (1999) note that capacity is often a short-run concept, as at least one input is held fixed at some level (e.g. vessel, technology). Capacity can thus be defined as the potential output level in the short run, based on the technological-engineering definition by Johansen (1968). FAO (1998, p.10) define capacity, consistent with economic theory of production, as follows:

"Fishing capacity is the maximum amount of fish over a period of time that can be produced by a fishing fleet if fully utilised, given the biomass and age structure of the fish stock and the present state of the technology".

However, it must be noted that an exclusion of biomass considerations could limit the usefulness of analyses in a management framework, since environmental conditions over time should to be incorporated. Indeed, the fluctuations in resource stock will impact fleet production considerably in a dynamic setting. Examples of such considerations include De Borger and Kerstens (2000) in their theoretical work on Malmquist productivity indexes and plant capacity utilization. Nevertheless, if management desires basic information on capacity and capacity utilization (i.e. what is the potential harvest given the size of the fleet and the potential use of inputs for a given biomass), many of these approaches could provide relatively useful information on the status of fishing fleets and the utilization of fishery resources in the short run (Gréboval, 1999).

In their technical consultation on measuring fishing capacity, FAO (2000) also discuss the detail of data required for capacity analysis, the limits of aggregation, and the measurement approach options. Among other things they state that when aggregated data are used, estimates will be crude and should be cautiously interpreted, and all underlying assumptions need to be made explicit. They further stress that results need to be compared for consistency. Aggregation can, for example, be across the fleet segments for a certain species or at the fleet level across species. Aggregation can further be defined at different levels, for example for a certain species, national and international stocks, or at the global level. Here they recognise that increasing the level of aggregation reduces the accuracy of the measure of capacity.

2.1 Catch-per-unit-effort

A simple indicator of capacity could be based on a catch per unit of effort (CPUE) analysis. Using aggregated data, this could simply be the volume or value of landings of the fleet divided by the number of GT-days or kW-days (product of vessel capital and vessel activity). Using both volume and value would help to identify more value-driven fisheries (e.g. fish for reduction fisheries are high-volume whereas cod fisheries are high-value). Distinguishing between GT and kW could be important since fleets are characterized by different physical factors (e.g. gear, proximity to fishing grounds).

CPUE can be calculated as follows:

$$CPUE_{GT,kW} = \frac{Catch}{Capital_{GT,kW} * DaysAtSea} \qquad (1)$$

Table 1: CPUE example

Unit	Catch (kg)	Days at sea	GT	KW	Catch/GT-day	Catch/kW-day
1	120 000	150	75	600	10.7	1.33
2	200 000	180	50	350	22.2	3.17
3	105 000	175	60	750	10.0	0.80
4	450 000	200	120	900	18.8	2.50
5	300 000	145	150	410	13.8	5.05
6	220 000	105	120	600	17.5	3.49

Table 1 above illustrates a simple estimation of this indicator. From the view of economic theory, CPUE serves a direct indicator of production in relation to the fixed and variable inputs applied, and can hence be directly compared to a standard production function in industry. Catch output can also be given in revenue terms, allowing the estimation of a value per unit effort (VPUE) indicator. Agreeably, all factors of production are not captured in the effort unit, but it should still be regarded as a general

productivity indicator that shows the average output per aggregate input, assuming constant returns to scale. It can also serve as an indicator of changes in stock biomass (Cochrane, 2002). Simple indicators of catch and revenues per employment number can also be insightful from a socio-economic perspective.

The Johansen (1968) capacity measure and even peak-to-peak find essentially the maximum average product of a single capital stock, *Y/K*. CPUE is analogous in the sense of *Y/E*. Both *Y/K* and *Y/E* are partial productivity measures. However, *Y/K* measures capacity since capacity is comprised of the capital stock or capacity base, whereas *E* merely relates to utilization or a service flow and not strictly related to capacity. Hence, *Y/K*E* is catch per unit of the flow of capital services (Squires 2003, personal communication).

2.2 Variable input utilization

The FAO (1998) definition of capacity refers to full utilization (of variable inputs). Hence, it would make intuitive sense to directly analyse the utilization of variable inputs, in this case the number of days at sea. This would indicate the possible increase in capacity utilization were vessels not influenced by management restrictions, weather, economic considerations, skipper behaviour/strategy, etc. It is clear that the number of days at sea opted for is at least partly based on direct considerations given to economic factors. In other industries, the number of operating days per year remains relatively fixed (e.g. electric utilities).

As outlined in the Commission's Green Paper (DG Fisheries 2001), concerning the revision of the CFP, the utilization rate of capacity can be calculated by comparing the total number of observed days at sea with the potential capacity. In the paper it is assumed that potential capacity is 265-days per vessel per year. Such an estimate is obviously highly dependent on *inter alia* management restrictions (e.g. effort-based regulation, quota allocations), fishing patterns and fishery characteristics.

Variable input utilization (VIU) can hence be estimated as follows:

$$VIU = \frac{DaysAtSea(observed)}{DaysAtSea(potential)} \qquad (2)$$

A simple illustration for a vessel with 172 days per year is thus 172 divided by 265, equalling a utilization rate of 0.65, or 65. The potential number of days is extremely fishery specific and 265 days, as used by the Commission, immediately seems to be in excess of what many fisheries can realistically exert (if weather, maintenance, management restrictions, etc. are taken into account).

Kirkley and Squires (1999) provide further insight into VIU analysis, with an application to the US northwest Atlantic sea scallop fishery. They acknowledge that the only way to accurately determine the maximum potential number of days at sea for a given fleet is to conduct very extensive economic and social surveys and analyses, and hence limit the use of VIU in a more generalised setting.

2.3 Peak-to-peak

Where only basic catch and aggregated fleet data are available, Gréboval (1999) propose that peak-to-peak (PTP) time series analysis be applied. Based on among others Klein (1960) and Ballard and Roberts (1977), historical capacity utilization rates can be obtained by comparing catch rates of both peak and non-peak years, incorporating adjustments for productivity changes and assuming an underlying production function. That is, the approach derives measures of capacity utilization by comparing capacity output to actual output levels in different time periods, and hence depends on reliable panel data. Output can be given as catch or in monetary (revenue) terms. PTP should however be regarded as a rather ad hoc approach. Empirical applications include Pacific fisheries in the United States by Ballard and Roberts (1977) and worldwide capacity estimations by Garcia and Newton (1997). Similar approaches to technologically derived maximum possible output include fleet hold

capacity, maximum sustainable yield, and the fishing mortality approach, as discussed by Kirkley, Squires in Gréboval (1999).

The first step of the approach is to calculate a technology trend, based on the ratio of output to input, between two peak years of production (serving as primary reference points of capacity). Capacity utilization is subsequently calculated as the ratio of potential output to observed output per operating unit. A simple illustrative example is given below.

Table 2: Peak-to-peak example

Year	Catch	Operating units	Capacity utilization	Catch rate	
	(tonnes)			Possible	Observed
1995	500	50	100	10.0	10.0
1996	490	48	97	10.5	10.2
1997	410	40	94	11.0	10.3
1998	475	42	98	11.5	11.3
1999	520	45	97	12.0	11.6
2000	500	40	100	12.5	12.5
2001	440	40	83	13.2	11.0
2002	435	38	82	13.9	11.4

Observed catch rates are calculated as catch divided by number of operating units. The peak years are defined by 1995 and 2000, and are given capacity utilization rates of 100 (full utilization), where the ratio value of output to capital stock is at a maximum.

In this case, the technology trend in the particular time period is determined by the average rate of change in productivity between the 1995 and 2000 peak years. Hence, given the data in Table 2 the technology trend will be:

$$TTrend = \frac{12.5 - 10}{5} = 0.5t / year \qquad (3)$$

The possible catch rate is then calculated from the 1995 peak year by adding 0.5 (the average rate of change in production) for each year until the 2000 peak year. The capacity utilization rate is then calculated for the intervening years as the ratio of observed catch rate divided by possible catch rate. For 1998 this would be 0.98 or 98 percent (11.3/11.5). The technology trend following the peak in 2000 is similarly found for the following years:

$$TTrend = \frac{11.4 - 10}{2} = 0.7t / year \qquad (4)$$

Here, 11.4 is the observed catch rate in the next peak year, i.e. in 2002. It is still compared to the peak catch rate in 1995, but here the trend only lasts for two years, i.e. 2001 and 2002. The new rate is added to the possible catch rate estimated for the 2000 peak, and so on.

If there appears to be insufficient peaks in the dataset or a lacking technology trend, an alternative Base Year comparison can be undertaken. Here, the following equation would hold:

$$TTrend = \frac{Y_{base}}{V_{base}} \qquad (5)$$

where Y is output, V is aggregate input, and the catch rate, representing the technology trend, is a constant. The catch rate of the base period can, for example, be calculated as the average of the first

few observations in each time series. From Table 3, this could be the average catch rate of 1995-96 (10.1). The possible (base) catch rate is then multiplied by the number of operating units in each year, to attain the potential catch output, and is then compared to the observed catch output to reach a level of capacity utilization. For 1998 this would be 0.99 or 99 percent (400/404).

Table 3: Base year comparison example

Year	Catch	Operating units	Capacity utilization	Catch rate	
	(tonnes)			Potential	Observed
1995	500	50	100	10.1	10.0
1996	490	48	101	10.1	10.2
1997	410	40	101	10.1	10.3
1998	400	40	99	10.1	10.0
1999	420	45	92	10.1	9.3
2000	285	30	94	10.1	9.5

It is clear that without taking a technology trend into account the capacity utilization rates will be higher in later years, if there is a rising trend in catch rates. For datasets where there are no clear or usable peaks, but there still appears to be some improvement in catch rates, it should therefore, be noted that the base year comparison will result in higher estimates of capacity utilization. In line with economic theory, this approach is a variant of the concept of economic capacity and defines a primal measure of capacity output (i.e. the maximum potential output given the harvesting technology, capital stock, and resource stocks). The peaks are identified as years that the industry was recognised as achieving the maximum sustainable output in the short run (Ballard and Roberts, 1977). Drawbacks of this approach seem to be the rather subjective nature of identifying peaks and technology trends in data of a limited time series, and the rather inexplicit treatment of negative technology trends.

2.4 Data envelopment analysis

Data Envelopment Analysis (DEA) has been identified as a viable and robust approach to measure the potential output of a fishery given the current structure of the fleet (Gréboval, 1999). Another approach often applied to efficiency analysis is stochastic production frontiers, although this approach is not considered here[6]. The DEA framework helps us assess fishing capacity, or production output from a fishery given the current level of production inputs, based on traditional efficiency analysis often undertaken in other industry sectors. A considerable advantage of DEA is that it allows the inclusion of multiple inputs and outputs. Comprehensive introductions to DEA can be found in Cooper, Seiford and Tone (2000) and Charnes *et al.* (1996). An application of DEA to fishing fleets in Europe is provided in Vestergaard *et al.* (2002).

With the DEA approach it is possible to determine the combination of variable inputs, outputs, the fixed factors, and the characteristics of the firms that maximize output, minimize input, or optimize revenue, costs, or profit. A strict economic approach to DEA can also be applied by using revenue maximization, employing output and output prices, although this is considered to be outside the scope of this analysis. An application of DEA revenue maximization is provided in Lindebo, Hoff and Vestergaard (2002) based on the approach provided by Färe, Grosskopf and Kirkley (2000). The standard physically based measure may be inappropriate in determining excessive productive capacity and overcapitalization since the underlying responses to demand and supply conditions are not considered. However, the physical approach does give useful information about excessive production possibilities relative to the resource (Gréboval, 1999).

DEA is a non-parametric mathematical programming approach that uses the optimization of an objective function given a series of constraints. It allows us to assess the efficiency of an existing technology relative to an optimal, "best practice", frontier technology observed in a given fishing fleet.

[6] Kirkley, Squires and Strand (1995) is the first example of applying stochastic frontier productions to fisheries.

The frontier technology from an output-orientation may resemble the optimal combination of inputs (e.g. tonnage, engine power) and catch output. The technique allows us to individually assess each input/output combination of each observation and compare it to the "best practice" producers. The analysis thus helps to identify the magnitude by which each vessel, for example, should be able to expand its output production if it were as efficient as the "best practice" vessel that uses the same level of inputs.

The estimation of capacity output can be obtained by solving a linear programming model, based on Färe, Grosskopf and Kokkenlenberg (1989), as follows:

$$\underset{\theta,z,\lambda}{Max}\ \theta_1 \qquad (6)$$

subject to:

$$\sum_{i-1}^{N} z_i y_{im} \geq \theta_1 y_{jm}, \forall m \qquad (7)$$

$$\sum_{i=1}^{N} z_i x_{in} \leq x_{jn}, n \in F_x \qquad (8)$$

$$\sum_{i=1}^{N} z_i x_{in} = \lambda_{jn} x_{jn}, n \in V_x \qquad (9)$$

$$z_i \geq 0, \forall i \qquad (10)$$

$$\sum_{i=1}^{N} z_i = 1 \qquad (11)$$

where θ_1 is the capacity measure, y_{jm} is the amount of output m produced by firm j, x_{jn} is the quantity of input n used by firm j, and z_i is the intensity variable for firm i.

Inputs are divided into fixed factors, defined by the set F_x, and variable factors defined by the set V_x. Equation (7) represents one constraint for each output, while Equation (8) constrains each of the fixed factors. Equation (9) allows the variable inputs to vary freely. Equation (10) is the non-negativity condition on the z variable and Equation (11) imposes variable returns to scale, and so allowing a combination of increasing, decreasing and constant returns to scale properties of capacity output production. Output produced by each firm can be given in either physical (kilograms) or economic (revenue) terms.

The model is run once for each observation/firm in the dataset. Capacity output is determined by multiplying θ_1 by observed output. Capacity utilization (CU) can be calculated using the observed output as follows:

$$CU = \frac{y}{\theta_1 y} = \frac{1}{\theta_1} \qquad (12)$$

The CU scores range from 0 to 1, with 1 representing full capacity utilization. Values of less than 1 indicate that the firm is operating at less than full capacity given the set of fixed inputs. It is foreseen that if a restricted number of observations are used, the robustness of the model will not result in representative or usable capacity utilization scores. That is, the input/output combinations of a few chosen firms in a small data sample will decide the efficient frontier production, and hence decide the relative efficiency of all other firms in the dataset. Cooper, Seiford and Tone (2000) introduce a rule of thumb for the degrees of freedom to be applied to DEA. Because of its orientation to relative efficiency the problem is compounded. The number of degrees of freedom will increase with the

number of observations and decrease with the number of inputs and outputs. A rough guideline as follows can thus be given:

$$n \geq \max\{m * s, 3(m + s)\} \qquad (13)$$

where n is the number of observations/firms, m is the number of inputs, and s is the number of outputs.

This is the most technical of the approaches considered in this paper. The DEA model is often formulated using programming software such as the General Algebraic Modelling System (GAMS)[7], or applied in more specialised software packages like ONFRONT and DEAP. An example of the GAMS programme applied in this paper is given in the Appendix.

2.5 Break even analysis

In cases where economic data are available, an analysis based on the principle of break-even revenues can be applied (Frost 2003, personal communication). Under open access equilibrium, where all rents are dissipated, total revenue equals total cost. Here, the Y break-even will coincide with Y cost minimization in Figure 1, and hence you can talk about bias of break-even as greater or lesser than cost minimization Y measure of capacity, depending on short or long run considerations and inclusions of variable and fixed costs (Squires 2003, personal communication).

The gross cash flow (GCF), which is gross output (revenue) less all variable (operation) costs, is central in the sense that the fisher will stay in the fishery in the short run if the GCF is positive, but in the long run he will stay only if the fixed costs are covered by the GCF. The revenue at which the GCF exactly equals the fixed costs can be defined as the "Break Even" revenue. It rests on the assumption that GCF per unit revenue is known, and the Break Even revenue is then calculated by use of the following expression:

Break Even revenue = Fixed costs / (GCF/Revenue) (14)

The economic sustainability and over-/undercapacity of a fleet segment can be calculated by taking the relation between the Actual (observed) revenue and the Break Even revenue. A simple example can be viewed below.

Gross output/revenue:	€ 150 million
Cash flow:	€ 20 million
Invested capital (IC):	€ 170 million
Fixed costs (at 11% of IC):	€ 18.7 million

From Equation (14) and assuming that average and marginal variable costs are equal and constant, we can hence calculate the following:

Break Even Revenue:	18.7/(20/150) = 140.25
Economic sustainability:	140.25/150 = 0.935

An economic sustainability of 0.935 represents a level of undercapacity where more revenue is being achieved than required to be economically sustainable in the long run. That is, more capacity could be introduced whilst still upholding the balance between observed revenues and the Break Even revenue.

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[7] Provided by Brooke, Kendrick and Raman (1998).

From the example above we can thus maintain that fixed costs could increase by seven percent, since:

Break Even score: 1/0.935 = 1.07

Conversely, an overcapacity would relate to a situation where a fleet is unable to achieve high enough revenues to cover fixed costs (i.e. disinvestment in capacity is needed) and would be represented by a Break Even (BE) score of less than 1.

This approach is directly linked to business-economics principles of the firm. If the revenue of a fleet segment, given a certain stock level, species composition, set of daily catch rates, and cost structure, is below Break Even revenue then a non-economic sustainable fishery can be defined, and vice versa. The definitions of economic sustainability and fixed costs (percentage of investment cost) in this analysis hinge on the strict assumption of constant returns to scale, and some caution should thus be taken given the variable returns to scale often observed in fisheries. Further, it is prudent to take an average of time series data to even out variations caused by changes in catch composition, fish prices, cost changes, etc. The concept is portrayed in Figure 2 below, with capacity along the X-axis defined as an input of production.

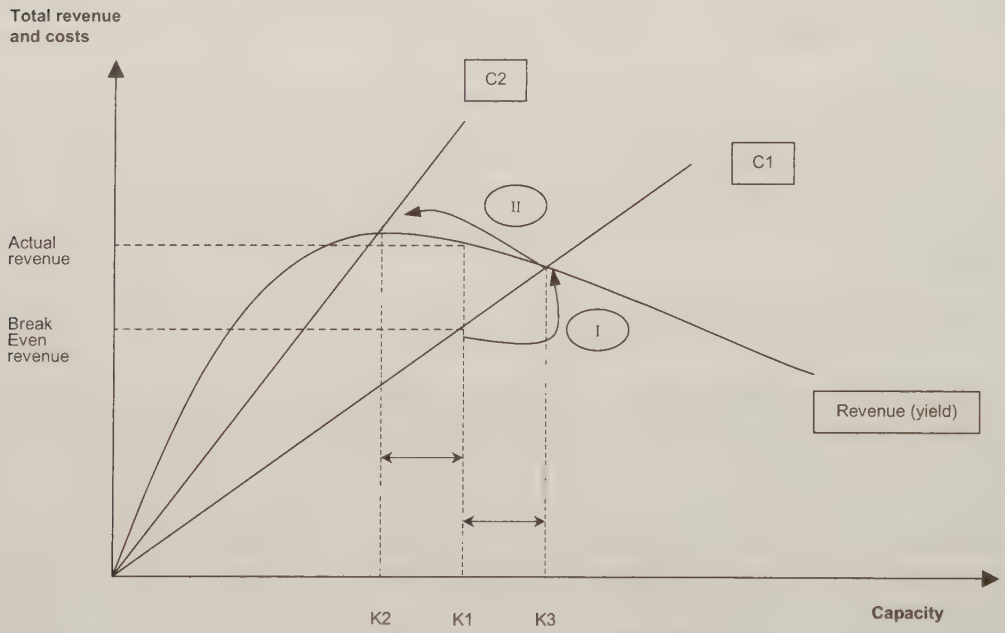

Figure 2: Economic sustainability and long-run overcapacity (Lindebo, Frost and Løkkegaard 2002)

If a fleet segment is in an initial position at K1 the first adjustment calculated by the Break Even revenue is from K1 to the intersection between the cost curve C1 and the revenue curve (step I), which also reflects the yield curve of a fish species. This shift could be defined as a move towards long run economic sustainability. The shift from K1 to K3 will occur as the excess profits (or part of it) will be invested in new capacity, or new capacity is being attracted because of the excess profit. The difference between K1 and K3 represents the undercapacity estimate in terms of economic sustainability given in the example above. Step II and the shift towards K2 represents the long run socio-economic sustainable situation, where the cost curve C2 is higher as a result of charging for access to the fish resource, for example. In this case, the difference between K1 and K2 would represent the level of over-/undercapacity. However, this second step is not applied to the capacity analyses of this paper.

3. AGGREGATED DATA ANALYSIS

3.1 Data description

Although the primary objective of this paper is to analyse various analytical tools, it is also interesting to consider the usefulness of compiled economic data initiated under the EU research framework. The availability of economic data are often quoted as a substantial stumbling block in fisheries economics research, and hence this paper serves as an example where the robustness and usefulness of aggregated data can be tested in an analytical setting. The aggregated European fleet segment data are sourced from the 2002 Annual Report of Economic Performance of Selected European Fishing Fleets (AER 2002), compiled under the guidance of the EU-funded Concerted Action "Economic Assessment of European Fisheries". The Annual Report offers aggregated physical and economic data for a range of fleet segments the years 1996-2001. Table 4 and 5 below outline the trawler fleets and associated data chosen for this analysis.

Table 4: Country fleet segments

Country		Fleet	Time series
Denmark	DEN	Trawlers < 200 GT	1996-2001
Faroe Islands	FAE	Pair trawlers > 1000 HP	1996-2001
Finland	FIN	Trawlers < 24 metres	1996-2001
France	FRA	Mediterranean trawlers 18-25 metres	1997-2001
Greece	GRE	Thermaikos coastal water trawlers	1996-2001
Italy	ITA	Trawlers	1996-2001
Netherlands	NET	Beam trawlers > 811 kW	1996-2001
Norway	NOR	Wetfish trawlers	1996-2000
Portugal	POR	Coastal trawlers	1996-2001
Spain	SPA	300's fleet vessels	1996-2001
Sweden	SWE	Cod trawlers < 24 metres	1996-2001
United Kingdom	UK	Scottish demersal trawlers 10-24 metres	1997-2001

Table 5: Annual economic and physical fleet indicators, 1996-2001 average

Country / Fleet	*Economic indicators*				*Physical indicators*				
	Value of landings	*Gross cash flow*	*Invested capital*	*Employ-ment*	*Volume of landings*	*Days at sea*	*Number of vessels*	*GT/GRT*	*Engine kW*
	(€ million)				(1 000 t)	(1 000)		(1 000)	(1 000)
DEN	152	20	164	1 723	271	99	554	24	134
FAE	21	5.2	22	219	24	4.3	16	6.0	15
FIN	7.8	0.9	10	176	53	11	98	3.7	23
FRA	64	15	28	712	20	28	151	7.9	44
GRE	5.2	0.8	12	115	1.5	7.1	38	2.7	13
ITA	519	123	946	9 792	110	404	2 305	98	502
NET	209	47	357	1 149	70	31	165	68	269
NOR	68	12	215	779	75	7.3	33	11	43
POR	46	10	40	1 250	24	30	109	18	53
SPA	168	37	45	3 270	32	53	207	41	88
SWE	10	3.2	17	113	4.2	6.4	51	2.5	13
UK	111	14	109	1 083	54	52	216	17	70

Source: AER (2002)

3.2 Analytical specifications

The specifications of the analyses are given in Table 6 below. All approaches, except DEA, apply the average annual data for each fleet in separate country analyses, which are then compared and contrasted. In the DEA analysis, however, the data of each separate fleet segment for each year acts as one observation in an all-in-one analysis, comparing observations in a relative performance setting, as outlined in Section 2.4. The GAMS programme used for the analysis is outlined in the Appendix.

Table 6: Specifications of analyses

Analysis	*Data*	*Data application/runs*	*Other specifications*
CPUE	*Landing volume, kW-days, GT-days*	*Annual average/ separate*	-
VPUE	*Landing value, kW-days, GT-days*	*Annual average/ separate*	-
Employment	*Landing volume/value, employment*	*Annual average/ separate*	-
PTP – volume	*Landing volume, kW, GT*	*Annual average/ separate*	*Standard, base year*
PTP – value	*Landing value, kW, GT*	*Annual average/ separate*	*Standard, base year*
VIU	*Days at sea*	*Annual average/ separate*	*265 'potential days'*
DEA – volume	*Landing volume, kW, GT, days at sea*	*Annual average/ all-in-one*	*Run in GAMS*
DEA – value	*Landing value, kW, GT, days at sea*	*Annual average/ all-in-one*	*Run in GAMS*
BE score	*Landing value, gross cash flow, invested capital (IC)*	*Annual average/ separate*	*Fixed costs = 11% of IC*

The approximation of fixed costs (11 percent of IC) is based on an opportunity cost of capital of seven percent and depreciation of four percent. There is considerable debate in the literature concerning the opportunity cost of capital, e.g. private opportunity cost versus social opportunity cost. Further, national treasuries will invariably recommend the rates to be applied for analytical purposes, and the rate will impact results significantly (a high rate will prejudice those nations with large capital investments). Kirkley and Squires (1988) further suggest that more research is required on the social discount rate, reasons for investment, and the marginal productivity of capital.

The contrast in fleet segment characteristics, in terms of species and fishery characteristic and variable management restrictions, does not allow this paper to draw generalised conclusions regarding the capacity of the trawler fleets. Given the non-comparable nature of scores, each analysis is also summarised by a ranking score to assist in the interpretation of results. Although these scores should still be viewed with some caution, they may still allow for a comparison of variability between the range of methodologies considered.

3.3 Results

In this section the results of the various approaches are given as overall average indicators for the time series of the chosen fleet segments (i.e. an average score for the fleet during 1996-2001). The range of approaches clearly gives deviating indicators of capacity as portrayed in Tables 8 and 9. The CPUE, VPUE and Employment capacity indicators have been normalized for easier interpretation. Table 7 provides further insight into deviations among the results and give approximate indications of the best and worst performers in the aggregated data analysis.

The CPUE and VPUE capacity scores both indicate that the Faroe Islands fleet is the most efficient with Italy being the worst performing fleet. Both Finland and Denmark clearly show more favourable CPUE scores than in the VPUE case, whereas many southern European countries benefit in relative terms under the VPUE approach. This may be an indication of differences between volume- and value-driven fisheries. Differences between GT and kW indicators are also apparent, but without specific trends.

The VIU approach is based on rather basic assumptions of what is the maximum or 'optimal' use of variable inputs. The tables clearly indicate that the fleet segments of Spain, Portugal and the Faroe Islands spend more days at sea than their counterparts. Contrary, Finland and Sweden have much lower days at sea utilization and the deviations of scores for Norway are notable. This may be an indication of differences between more technologically driven fisheries and coastal, labour-intensive fisheries, and is supported by Finland also being at the top of the employment indicator whilst Portugal is at the bottom.

The scores arising from the PTP approaches vary slightly depending on the capacity measure used (GT or kW), although there does not appear to be any specific pattern. Spain and the Faroe Islands were best performers of the volume PTP and value PTP respectively, whereas the United Kingdom was clearly the worst performer. The reason for the poor scores of the United Kingdom was in particular due to a negative technology trend when GT catch rates were applied.

The volume DEA approach clearly identifies all the Nordic fleet segments as being the most efficient in capacity terms. On the other hand, countries such as Spain, Portugal and Greece do not perform as well, possibly indicating that some of the more technologically driven fishing fleets are favoured. Interestingly, the value DEA approach turn some of these results around with Italy being the best and Finland the worst, although Portugal and Greece are still left towards the bottom of the rankings. However, it should be noted that using revenue as an aggregate output imposes some very strong assumptions on the nature of the aggregator function.

The Break Even approach indicates that there are greater capital investments in comparison to revenues for countries such as Norway, whereas Spain, Portugal and France have a more economically efficient foundation, at least given the assumptions of the Break Even approach. It is acknowledged, however, that the chosen interest rate may be too high and so prejudicing those fleets with higher capital investments in the more northern European countries.

Ranking the scores and simple addition helps us to identify further information that should be considered when attempting these forms of capacity analysis. Table 7 below shows the great variability in scores in relative ranking terms across approaches and fleet segments. It is interesting to note, for example, that the Faroe Islands fleet is clearly the best performer overall by some margin. Further, fleet segments of Finland, Italy and Portugal are both best and worst performers. It is hence interesting to note that despite the caution that is declared on the basis of the analysis, the same data has been applied for different approaches and assumptions, and the resulting scores vary substantially.

Statistical analysis was performed to help scientifically substantiate some of these general observations. The Wilcoxon sign rank test is a non-parametric test that allows for the analysis of the direction and magnitude of differences between two measures. That is, it tests whether noise on either side of the mean of two measures are normally distributed when compared to each other. In this case it involves the normalization of all capacity scores, with the highest score in each measure receiving the score 100, and then a standard execution of the Wilcoxon methodology (cf. Siegel and Castellan, 1988). A further simple analytical tool is a standard Spearman correlation, which allows for the direct comparison of two sets of measures. In unison, these two statistical approaches can determine the presence of statistically significant similarities or differences between two sets of capacity scores.

The results in themselves are rather inconclusive. The Wilcoxon test shows that the distributional differences on either side of the mean score between ten of the comparisons are equal. Most notably, VPUE/BE, DEAval/VIU, CPUE/BE, DEAvol/EMP and VPUE/DEAvol are significant at the 10 percent level, clearly allowing us to accept the null hypothesis that distributions are the same. That is, these distributional differences between these two sets of scores are the same. The Spearman correlation identifies a high correlation of scores of other sets of measures, in particular CPUE against VPUE, EMP and DEAvol, and PTPval/BE, which are all greater than 0.500. DEAvol/EMP is the only set of comparisons that is significant both in terms of correlations (greater than 0.500) and the Wilcoxon test. From an intuitive perspective, the similarity between DEAvol and EMP seems rather coincidental, since the underlying methodologies and data applications are in stark contrast to each other.

Table 7: Ranking of capacity indicators

Country	CPUE	VPUE	Employ	PTP-vol	PTP-val	DEA-vol	DEA- val	VIU	BE	Total	Rank
FAE	1	1	4	4	1	3	6	2	4	26	1
FRA	6	4	8	8	2	9	4	8	2	51	2
NOR	3	2	5	11	7	4	2	5	12	51	2
SPA	11	8	10	1	8	11	3	3	1	56	4
NET	10	9	2	3	4	8	9	6	6	57	5
DEN	5	11	3	6	9	2	7	9	8	60	6
FIN	2	6	1	5	11	1	12	12	10	60	6
SWE	4	3	7	10	10	5	8	11	5	63	8
POR	9	10	12	9	3	10	10	1	3	67	9
ITA	12	12	9	7	5	6	1	10	7	69	10
UK	8	7	6	12	12	7	5	4	9	70	11
GRE	7	5	11	2	6	12	11	7	11	72	12

Note: 1 is the most efficient and 12 is the least efficient

Table 8: Average capacity indicators

Country/	—— CPUE ——		—— VPUE ——		—— Employment ——		PTP-vol ——		—— PTP-val ——					
Fleet	GT	kW	GT	kW	kg per	€ per	GT	kW	GT	kW	VIU	DEA-vol	DEA-val	BE score
DEN	8.7	5.6	7.1	3.6	51	49	86	95	92	92	0.67	0.85	0.79	1.04
FAR	69	100	87	100	34	51	90	93	97	101	1.04	0.81	0.81	1.90
FIN	100	56	21	9.4	100	24	90	91	82	84	0.44	0.89	0.24	0.81
FRA	7.2	4.6	33	17	9.3	50	89	88	99	98	0.69	0.18	0.85	4.87
GRE	6.1	4.7	30	18	4.4	25	96	96	95	95	0.70	0.08	0.34	0.60
ITA	0.2	0.1	1.4	0.8	3.7	29	93	88	95	96	0.66	0.34	0.94	1.14
NET	2.6	2.3	11	8.0	20	100	95	95	93	100	0.70	0.21	0.59	1.18
NOR	79	71	100	71	32	49	77	78	98	91	0.83	0.69	0.86	0.45
POR	3.3	4.1	9.1	9.1	6.2	20	85	87	98	97	1.05	0.18	0.43	2.33
SPA	1.1	1.9	8.3	11	3.2	28	100	100	94	95	0.97	0.15	0.85	7.48
SWE	22	15	76	40	12	50	85	85	87	87	0.47	0.34	0.72	1.62
UK	5.6	4.1	16	10	16	56	61	81	67	91	0.90	0.33	0.84	0.94

Table 9: Coefficient of variance of capacity indicators

Country/	—— CPUE ——		—— VPUE ——		—— Employment ——		—— PTP-vol ——		—— PTP-val ——					
Fleet	GT	kW	GT	kW	kg per	€ per	GT	kW	GT	kW	VIU	DEA-vol	DEA-val	BE score
DEN	0.17	0.20	0.11	0.14	0.20	0.09	0.16	0.17	0.11	0.14	0.03	0.16	0.07	0.38
FAR	0.18	0.12	0.25	0.20	0.18	0.24	0.10	0.07	0.06	0.05	0.02	0.10	0.20	0.36
FIN	0.22	0.21	0.34	0.29	0.17	0.18	0.09	0.10	0.25	0.22	0.06	0.11	0.32	0.54
FRA	0.34	0.36	0.15	0.17	0.30	0.10	0.20	0.20	0.03	0.03	0.02	0.32	0.27	0.72
GRE	0.10	0.10	0.12	0.12	0.10	0.11	0.10	0.10	0.07	0.07	0.03	0.15	0.13	0.25
ITA	0.12	0.17	0.03	0.07	0.10	0.08	0.09	0.12	0.06	0.05	0.05	0.10	0.05	0.24
NET	0.06	0.06	0.10	0.11	0.04	0.08	0.05	0.05	0.08	0.03	0.03	0.06	0.06	0.14
NOR	0.46	0.46	0.25	0.24	0.19	0.13	0.29	0.29	0.04	0.14	0.15	0.28	0.08	0.44
POR	0.18	0.16	0.12	0.13	0.13	0.15	0.20	0.18	0.10	0.10	0.08	0.18	0.09	0.25
SPA	0.10	0.12	0.10	0.12	0.12	0.15	0.12	0.13	0.06	0.05	0.03	0.10	0.10	0.38
SWE	0.29	0.26	0.32	0.28	0.18	0.18	0.18	0.18	0.18	0.14	0.10	0.96	0.28	0.25
UK	0.58	0.24	0.48	0.14	0.19	0.07	0.59	0.25	0.48	0.14	0.05	0.30	0.21	0.55

4. DISAGGREGATED DATA ANALYSIS

4.1 Data description

It is beneficial to undertake similar capacity analyses on disaggregated data. This allows for more direct efficiency comparisons of vessels of similar gear characteristics and fishery patterns. Here, less attention is given to the identification of best and worst performing vessels, with greater emphasis given to the identification of potential systematic trends in capacity scores.

The data are structured as in the previous aggregated analysis. The Danish 12-24 m trawler fleet has been chosen, given its relatively homogeneous nature, with data being sourced from the FOI (Danish Research Institute of Food Economics (www.foi.dk), fishery account statistics database for 1996-2001). Incidentally, this is the same database that supports the Danish section of the AER report. Annual aggregated data for 14 vessels in the fleet with similar consumption fishing strategies throughout the period is applied. Annual economic and physical indicators of the vessels are depicted in Table 10 below. Indicators are also given for an average 'fleet' vessel based on the 14 vessels in the dataset.

Table 10: Annual economic and physical vessel indicators, 1996-2001 average

Vessel	Economic indicators				Physical indicators			
	Value of landings	Gross cash flow	Invested capital	Employment hours	Volume of landings (t)	Days at sea	GT/GRT	Engine kW
	(1 000 DKK)							
1	1 714	175	963	6 147	44	184	19	213
2	1 353	145	1 200	5 134	136	186	19	217
3	2 019	230	1 604	4,736	67	156	15	99
4	2 519	365	2 837	7 026	154	219	42	298
5	3 840	663	2 251	12 459	232	196	45	220
6	3 701	600	2 477	9 788	141	190	49	355
7	2 831	589	2 761	8 364	682	205	18	324
8	5 150	982	7 587	10 821	282	240	78	552
9	5 169	1 339	4 302	10 127	181	246	69	272
10	2 742	483	3 372	14 205	159	220	41	246
11	1 149	60	897	5 303	112	187	17	125
12	1 754	568	1 377	6 174	176	173	19	221
13	2 657	654	1 811	6 183	112	169	41	206
14	1 677	159	1 662	6 071	48	179	19	199
Fleet	2 734	501	2 507	8 038	180	197	35	253

Source: FOI fishery account statistics database (extracted 18.7.2003)

The analytical specifications are as outlined in Table 6 in the previous analysis, although now each vessel serves as the observation and not an aggregated fleet segment. The PTP volume approach applies the base year comparison due to the lack of observable peaks in the dataset, whereas the PTP value approach applies the standard approach. Since the analysis considers fishing vessels of similar character, direct comparison of scores is more feasible, although relative rankings are still used to simplify the interpretation of results.

4.2. Results

The discussion of results arising from the disaggregated analysis can take the form of the previous analysis, where fleets of various nations were directly compared with specific attention given to underlying production function differences between Northern and Southern Europe. However, it may be more appropriate to discuss whether the application of disaggregated data of similar vessel technologies have helped to shed more light on similarities between capacity approaches, and whether much can be said about overall application and reliability of these approaches.

At first glance there certainly appears to be slightly more consistency in scores than in the previous analysis, at least if the simple rankings of scores in Table 7 and Table 11 are contrasted. There are again similar observations to previously where some vessels are both worst and best performers, and some vessels are clearly more efficient than others, which is to be expected. However, there again seems to be little evidence of systematic trends. That is, the analysis is capable of identifying the efficient vessels using the various approaches but there is still sufficient noise in the results to maintain caution when interpreting the results. Disaggregation has thus at first glance been unable to contend with measurement differences and a next approach may hence be to consider the application of a larger dataset.

As in the aggregated data analysis, the nonparametric Wilcoxon and Spearman correlation tests are undertaken in order to substantiate the more qualitative observations above. At the 10 percent level, measure comparisons of VPUE/BE, PTPvol/DEAval, DEAval/VIU and BE/DEAvol are all significant. That is, the distributional differences on either side of their respective means are considered to be the same. The Spearman correlation, however, identifies a high correlation between scores of other sets of measures, in particular CPUE/DEAvol, EMP/PTPvol, EMP/DEAval and DEAval/BE, which are greater than 0.500. There are only two sets of comparison that are significant in both tests, namely VPUE/BE and DEAval/VIU, compared to DEAvol/EMP in the previous aggregated analysis. It is pleasing to see some statistical similarity between scores, and the more revenue-based measures of VPUE/BE is particularly intuitive. However, this proven similarity is still some way from being allowing us to conclude that the two methodologies will give similar scores if other datasets are applied. Hence, the potential benefits arising from using more disaggregated data cannot be readily identified through the statistical analysis.

Table 11: Ranking of capacity indicators

Vessel	CPUE	VPUE	Employ	PTP-vol	PTP-val	DEA-vol	DEA-val	VIU	BE	Total	Rank
7	**1**	2	**1**	2	4	2	4	5	4	25	1
9	10	6	2	**1**	11	8	**1**	**1**	3	43	2
5	3	3	10	12	6	4	3	6	2	49	3
3	5	**1**	5	4	12	**1**	5	14	5	52	4
13	7	4	4	5	6	10	8	13	**1**	58	5
12	2	5	7	8	3	5	9	12	8	59	6
8	11	13	3	6	9	6	2	2	9	61	7
11	4	10	11	3	**1**	3	14	8	11	65	8
6	12	8	8	7	8	12	6	7	6	74	9
10	8	11	14	12	5	8	7	3	7	75	10
4	9	14	6	11	13	11	9	3	10	86	11
14	13	7	12	10	1	13	12	11	12	91	12
2	6	12	9	14	9	7	13	9	14	93	13
1	14	9	13	8	14	14	9	9	13	103	14

Note: **1** is the most efficient and 14 is the least efficient

Table 12: Average capacity indicators

	----- CPUE -----		----- VPUE -----		---- Employment ----		----- PTP-vol -----		----- PTP-val -----					
Vessel	GT	kW	GT	kW	kg per	DKK per	GT	kW	GT	kW	VIU	DEA-vol	DEA-val	BE score
1	6.8	12	54	33	8.9	51	92	84	81	79	0.70	0.08	0.49	0.73
2	21	33	43	25	33	49	79	79	87	87	0.70	0.22	0.38	0.54
3	16	44	100	100	18	80	98	98	84	84	0.59	0.77	0.69	1.84
4	9.1	23	30	28	27	66	88	83	80	85	0.83	0.16	0.49	1.05
5	14	53	49	66	23	57	84	84	93	93	0.74	0.37	0.75	2.67
6	8.4	21	46	42	18	70	90	90	88	88	0.72	0.13	0.66	1.58
7	100	100	86	31	100	62	100	100	95	95	0.77	0.63	0.74	1.86
8	8.2	21	31	29	33	89	92	92	87	87	0.91	0.26	0.77	1.09
9	5.8	26	34	57	24	100	126	118	86	87	0.93	0.21	0.78	2.24
10	10	29	36	38	14	37	87	81	94	94	0.83	0.21	0.56	1.30
11	19	47	40	36	26	41	99	99	102	102	0.71	0.55	0.37	0.98
12	29	46	59	33	37	52	88	88	100	100	0.65	0.28	0.49	1.17
13	8.8	32	43	56	23	79	94	94	93	93	0.64	0.20	0.55	3.13
14	7.7	13	55	35	10	51	87	87	102	102	0.68	0.09	0.48	0.81

Table 13: Coefficient of variance of capacity indicators

	----- CPUE -----		----- VPUE -----		---- Employment ----		----- PTP-vol -----		----- PTP-val -----					
Vessel	GT	kW	GT	kW	kg per	DKK per	GT	kW	GT	kW	VIU	DEA-vol	DEA-val	BE score
1	0.07	2.75	0.16	0.24	0.15	0.16	0.21	0.35	0.35	0.39	0.09	0.42	0.19	1.00
2	0.20	3.66	0.23	0.23	0.37	0.24	0.38	0.38	0.19	0.19	0.04	0.38	0.22	1.03
3	0.11	1.94	0.20	0.20	0.18	0.26	0.20	0.20	0.17	0.17	0.34	0.20	0.25	0.43
4	0.08	1.86	0.14	0.10	0.13	0.16	0.15	0.19	0.26	0.22	0.00	0.21	0.14	0.33
5	0.12	2.16	0.21	0.21	0.20	0.19	0.19	0.19	0.11	0.11	0.12	0.19	0.13	0.15
6	0.09	1.66	0.28	0.28	0.11	0.17	0.10	0.10	0.18	0.18	0.14	0.10	0.13	0.69
7	0.18	3.31	0.23	0.23	0.32	0.19	0.35	0.35	0.07	0.07	0.04	0.35	0.22	0.23
8	0.09	1.69	0.13	0.13	0.27	0.15	0.18	0.18	0.18	0.18	0.09	0.18	0.11	0 36
9	0.14	2.26	0.27	0.24	0.34	0.35	0.22	0.20	0.31	0.31	0.07	0.19	0.21	0.59
10	0.09	1.39	0.28	0.20	0.11	0.22	0.15	0.22	0.11	0.12	0.23	0.22	0.11	0.35
11	0.08	1.45	0.26	0.26	0.19	0.32	0.15	0.15	0.09	0.09	0.06	0.15	0.23	1.32
12	0.13	2.40	0.13	0.13	0.32	0.08	0.16	0.16	0.05	0.05	0.09	0.16	0.19	1.05
13	0.07	1.17	0.12	0.12	0.20	0.05	0.10	0.10	0.19	0.19	0.05	0.10	0.11	0.25
14	0.14	2.48	0.17	0.17	0.24	0.16	0.21	0.21	0.17	0.17	0.06	0.21	0.13	0.56

4.3 Dynamic analysis

A final step of the analysis is to look at some of dynamic changes in capacity indicators of an average vessel in the fleet. This may again allow us to consider similarities and differences in the context of indexed development of capacity indicators for the 1996-2001 period (cf. Table 14 and Figure 3).

The analysis helps to further illustrate the obstacles associated with the application of various capacity measurement approaches. Two important observations are made. Firstly, the overall trend in indexed capacity over time is highly variable. Some approaches portray an improvement in efficiency whereas others indicate a decline in efficiency. It should be noted that this is observed for an average vessel, and hence it can be expected that using aggregated fleet data in this case will give highly variable capacity indicators under the various approaches.

Secondly, and perhaps more notable, is that certain approaches seem to nevertheless have similar trends over time, as depicted in Figure 3. VPUE-kW, EMP-DKK, and DEA-VAL, all linked to economic factors, show a general rising efficiency trend until 1999 followed by a slight decline. The BE score is not plotted but also has a similar rise and fall trend, albeit at a higher index level (and is thus not plotted). It is interesting to note, on the other hand, that CPUE-kW, EMP-KG, PTPVOL/VAL-kW and DEA-VOL all have declining trends in indexed efficiency over the time period. All but one of these approaches are based on purely physical factors. This would intuitively indicate that these capacity/efficiency measurements are higher when economic factors are considered. This may simply be because, for example, that although catch weights over time decline catch revenues are still upheld due to increasing fish prices. No appropriate statistical means are available for further analysis of these results here, but these findings should still be regarded as a beneficial addition to the comparisons of capacity measurement approaches. This is especially pertinent given that such general observations between physical and economic approaches could not be made, or indeed statistically proven in the previous analyses.

Table 14: Average fleet capacity indicators

	----- CPUE -----		----- VPUE -----		---- Employment --		----- PTP-vol -----		----- PTP-val -----					
Fleet	GT	kW	GT	kW	kg per	DKK per	GT	kW	GT	kW	VIU	DEA-vol	DEA-val	BE score
1996	19	38	40	35	30	52	98	98	100	100	0.76	0.32	0.47	0.85
1997	20	37	44	39	30	58	102	102	102	103	0.78	0.32	0.56	1.93
1998	18	36	53	47	29	67	94	92	96	96	0.70	0.28	0.59	1.98
1999	17	36	59	52	26	71	90	88	92	92	0.68	0.27	0.63	1.44
2000	18	34	53	45	27	70	88	84	80	80	0.74	0.29	0.62	1.08
2001	21	34	53	43	27	62	87	83	76	76	0.78	0.30	0.64	1.02
1996-2001	19	36	50	44	28	63	93	91	91	91	0.74	0.30	0.59	1.25

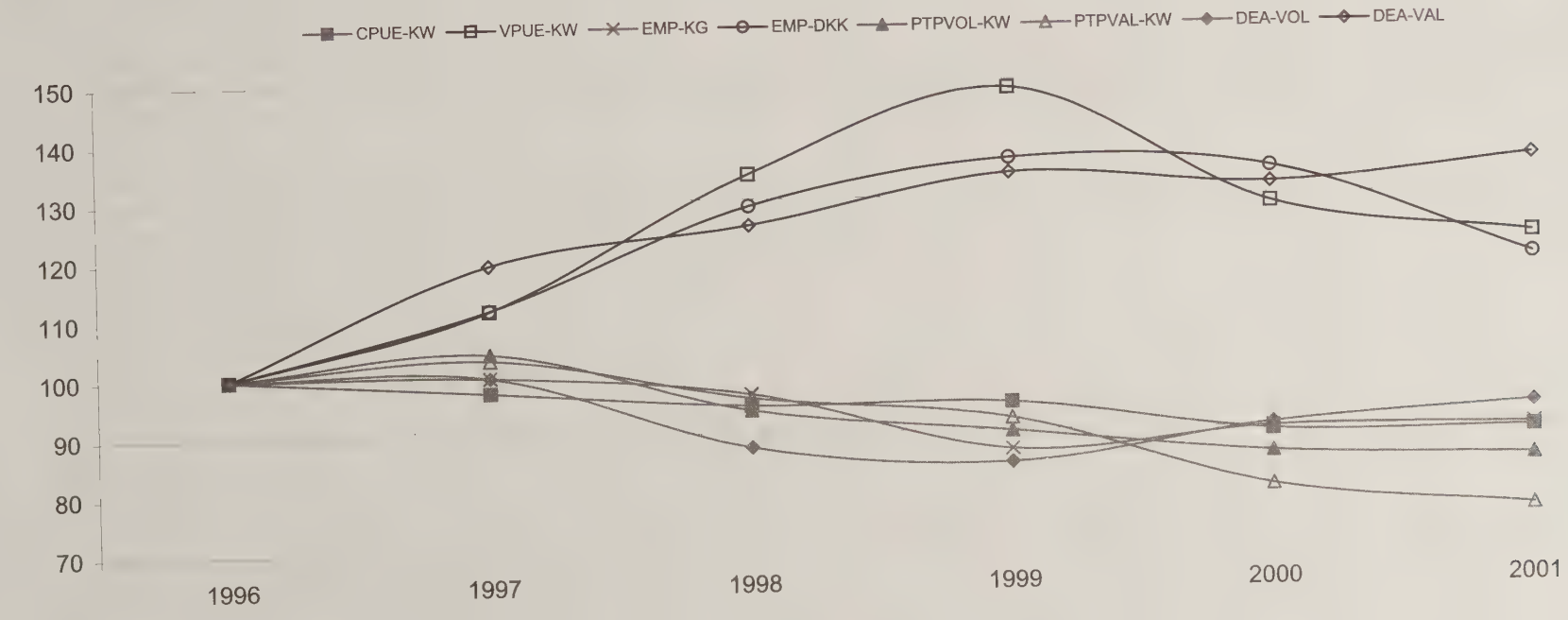

Figure 3: Indexed change in fleet capacity indicators (1996=100)

5. CONCLUDING REMARKS

The aims of this paper have been ambitious. An array of capacity measurement tools are available, which can be applied to both aggregated fleet data and disaggregated vessel data of similar operative characteristics. This paper has helped to outline the various tools available and applied readily available data in a practical setting, a step that has been seemingly lacking following the FAO capacity measurement initiative. It is expected that through the application of data will help to distinguish the problems associated with aggregation levels and also help to identify systematic similarities and differences between the various approaches. Indeed, from the theoretical discussion it can be acknowledged that the measurement approaches build on very different assumptions of what defines production efficiency. However, it might still be expected that some trends and similarities in relative scores can be found, further clarified through the application of more disaggregated data.

It is probably most important to consider the relative rankings and overall trends of scores rather than their absolute values. Both the aggregated and disaggregated analyses have in this fashion been able to provide estimates of the most efficient fleets and vessels, although any management implications based on these estimates should not be drawn. For example, in the aggregated analysis, fleets of Northern Europe seem to favour better when more technically-oriented production is assumed, whereas some of the more Southern European fleets are favoured when investment costs are accounted for. These estimates are highly data dependent, however. Through statistical analysis, using Wilcoxon and Spearman correlation, similarities are examined between different measures, but few conclusive or intuitive results are attained. Indeed, the differences in capacity measurement approaches seem too big to give any real consistency across the board. The application of disaggregated vessel data also indicates these variable tendencies, despite again being able to identify some of the more efficient operators in the dataset. This uncertainty is a conclusive result in itself, showing that irrespective of data and data aggregation, the results of the various approaches can expect to differ considerably. The final dynamic analysis has however indicated that there could be some general trends of capacity indicators over time, with physical and economic approaches showing different developments. This has however not been substantiated through further analysis and statistical testing.

As outlined in this paper, the various approaches have contrasting assumptions and data requirements and hence scores can be expected to differ considerably. It is hence more relevant to look at how various approaches change the overall results in relative terms. This is especially important in the context of capacity analysis, since many of the approaches have been suggested in the literature, but little consideration has been given to impacts on results in a management setting. For example, if we wish to analyse a certain fleet segment, what kind of approach should we use and what restrictions and assumptions do we need to be aware of when interpreting results. This is even more pertinent if one wishes to analyse more than one fleet segment of variable vessel and fishery characteristics. Do we use physical or economic data, what vessel inputs are most relevant, how are variable inputs impacted by external factors, do we need time series data, and is our analysis short or long term? This is only a fraction of the issues that need addressing when choosing an appropriate approach for capacity measurement and analysis. Capacity can be regarded in many ways and it is up to managers to set guidelines for what they judge to be an efficient vessel, be it in terms of physical or economic data, variable or fixed inputs, or other factors that influence a fisher's operation.

From a European fisheries management perspective, and the future role of capacity analysis in a scientific peer review process, this paper is a useful contribution. This is despite the lack of immediate scientifically proven results that may have proved beneficial to managers in their quest for better balance between fleets and resources and a better understanding of production dynamics and efficiency. It is nevertheless the concluding opinion of the author that these kinds of analyses be extended and elaborated in a practical setting, if purposeful inroads with regards to capacity analysis of fishing fleets are to be made. This paper has helped to shed light on issues arising from applying various measurement tools and variable data aggregation, and now it is a matter of extending these ideas to a more extensive analytical framework.

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APPENDIX

GAMS PROGRAMME FOR DEA APPROACH

```
SET INOUT /volume, vessels, grt, kw, effort, /
OUTPUT(INOUT) /volume/
INPUT(INOUT) /vessels, grt, kw, effort/
FIXED(INOUT) /vessels, grt, kw/
VAR(INOUT) /effort/
OBS /1*13/
SUBOBS(OBS) /1*13/
ACTOBS(OBS);

Alias (subobs, subobs1)
* 1 output
*  4 inputs 3 fixed and 1 variable

TABLE ACT(OBS,INOUT) INPUT OUTPUT
TABLE
$INCLUDE "c:\windows\EUcap\dasvessel.txt";
SUBOBS(OBS)=no;
subobs(obs)=yes$sum(inout, act(obs,inout));

VARIABLES
theta    efficiency score
weight(obs)  weights
Lambda(obs, VAR)

Positive Variable weight, lambda;


EQUATIONS

CONSTR1(OUTPUT,OBS) DEA constraint for
each output
CONSTR2(FIXED, OBS) DEA constraint for fixed
inputs
CONSTR3(VAR,OBS) DEA constraint for variable
inputs
CONSTR4 DEA constraint for variable returns to
scale
CONSTR5(INPUT,OBS) DEA constraint for each
input;

CONSTR1(OUTPUT,ACTOBS)..
SUM(SUBOBS,WEIGHT(SUBOBS)*ACT(SUBO
BS,OUTPUT))/1000=G=
theta*ACT(ACTOBS,OUTPUT)/1000;

CONSTR2(FIXED,ACTOBS)..
SUM(SUBOBS,WEIGHT(SUBOBS)*ACT(SUBO
BS,FIXED))=L=
ACT(ACTOBS,FIXED);

CONSTR3(VAR,ACTOBS)..
SUM(SUBOBS,WEIGHT(SUBOBS)*ACT(SUBO
BS,VAR))=E=
LAMBDA(ACTOBS,VAR)*ACT(ACTOBS,VAR);


CONSTR4..
SUM(SUBOBS, WEIGHT(SUBOBS))=E=1;

CONSTR5(INPUT,ACTOBS)..
SUM(SUBOBS,WEIGHT(SUBOBS)*ACT(SUBO
BS,INPUT))=L=
ACT(ACTOBS,INPUT);



PARAMETER
capscore(obs) theta estimates
varscore(obs,VAR) hold variable input levels;

MODEL CAP /CONSTR1, CONSTR2, CONSTR3,
CONSTR4/;

MODEL TECHEFF /CONSTR1, CONSTR4,
CONSTR5/;


option iterlim = 100000;

solving the capacity problem  phase I

LOOP(SUBOBS1,
 ACTOBS(OBS)=NO;
 ACTOBS(SUBOBS1)=YES;
 theta.l = 1;
 SOLVE CAP maximising theta using NLP;
 capscore(SUBOBS1)=theta.l;
varscore(SUBOBS1,VAR)=LAMBDA.L(SUBOBS
1,VAR);
 put dea;
 if((cap.modelstat eq 1 and cap.solvestat eq 1),

put@1,subobs1.tl,@10,"optimal",@20,"normalcom
pletion"/
  else
 put@1,subobs1.tl,@10,cap.modelstat:>2:0,@20,
  cap.solvestat:>2:0/ ));

DISPLAY CAPSCORE;
```

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